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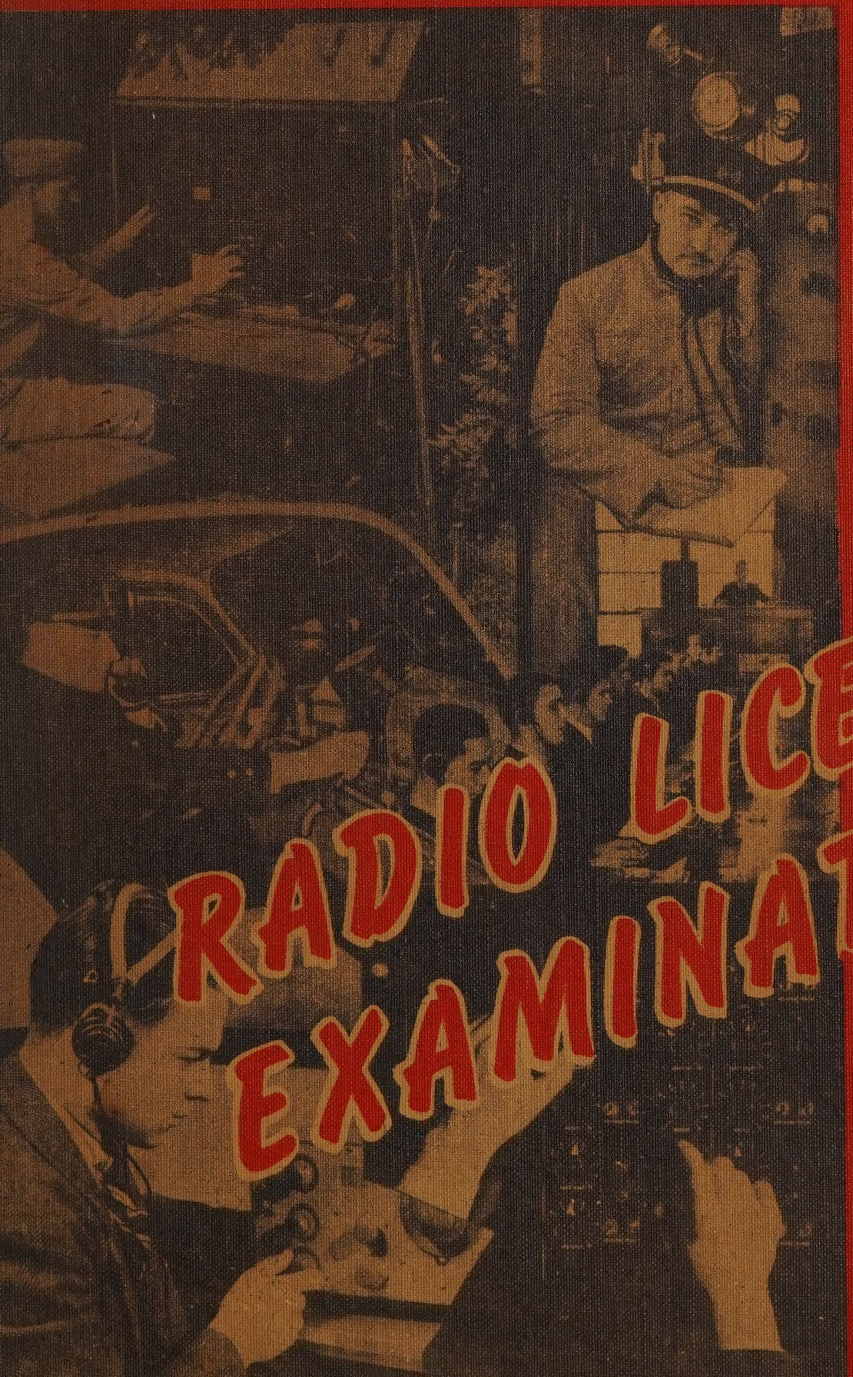

RADIO LICENSE EXAMINATIONS

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HOW TO PASS
Radio License Examinations

BY

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SECOND EDITION

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FOREWORD

The present day commercial radio operator license examinations cover a wide range of subjects, which makes it necessary for those desiring to qualify for licenses to be well-informed in both theory and practice. The coverage of subjects is suggested by the many questions given in the *Study Guide* issued by the Federal Communications Commission.

In this edition a considerable amount of information has been included in the form of discussions and explanations. This part of the text is a special feature because it provides necessary review material which otherwise could not be included without confusion with the answers to the regular questions. Important reasons for including additional subject matter in the form of discussions and explanations are to give the reader the greatest help in answering typical questions that are likely to be asked in an examination of this kind and to give sufficient added information to short answer questions where necessary to cover the reasons for a given subject.

This edition contains considerable material dealing with modulation, oscillators, classes of amplifiers, and rectifier power supplies. Also, a good portion of new material is given over to the operation of circuits to provide maximum frequency stability of a transmitter. Included are many problems dealing with percentage modulation and questions on typical troubles and causes of distortion of an audio signal.

The author wishes to acknowledge with grateful appreciation the portions of text matter contributed by Messrs. George F. Maedel, Oliver A. Meixell, and Albert Preisman.

C. E. D.

February 1944

ELEMENT 1

BASIC RADIO LAWS

101.01 to 101.05 inclusive. *Note.* These questions with answers are given at the end of Element 1 to conform with the sequence of arrangement in the *Study Guide* for Commercial Radio Operator Examinations.

111.01. *Question.* State five grounds on any one of which the Federal Communications Commission has authority to suspend a radio operator's license or permit. (Sec. 303*m*.) *

Answer. The F.C.C. (Federal Communications Commission) has authority to suspend the license of any operator upon proof sufficient to satisfy the Commission that the operator

(*a*) Has violated any provision of any Act, treaty, or convention binding on the United States which the Commission is authorized to administer, or any regulation made by the Commission under any such Act, treaty, or convention; or

(*b*) Has failed to carry out a lawful order of the master or person lawfully in charge of the ship or aircraft on which he is employed; or

(*c*) Has willfully damaged radio apparatus or installations or permitted same to be damaged; or

(*d*) Has transmitted superfluous radio communications or signals or communications containing profane or obscene words, language, or meaning, or has knowingly transmitted

(1) False or deceptive signals or communications, or
(2) A call signal or letter which has not been assigned by proper authority to the station he is operating; or

(*e*) Has willfully or maliciously interfered with any other radio communications or signals; or

(*f*) Has obtained or attempted to obtain, or has assisted another to obtain or attempt to obtain, an operator's license by fraudulent means.

111.02. *Question.* Is an operator subject to the penal provisions of the Communications Act if he violates the terms of a radio treaty to which the United States is a party? (Sec. 303*m* and 502.)

Answer. Yes. Any person who willfully and knowingly violates any rule, regulation, restriction, or condition made or imposed by the Commission under authority of this Act, or any rule, regulation, restriction, or condition made or imposed by any international radio or wire communications treaty or convention, or regulations annexed thereto, to which the United States is or may hereafter become a party, shall, in addition to any other penalties provided by law, be punished, upon conviction thereof, by a fine of not more than $500 for each and every day during which such offense occurs.

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*KEY TO ABBREVIATIONS: (See Appendix II.)

Sec. Refers to a section of the Communications Act of 1934.
Art. Refers to an article of the General Radio Regulations (Cairo).
R. & R. Refers to a provision of the Rules and Regulations of the Federal Communications Commission.

111.03. *Question.* State at least two provisions made in the Communications Act to ensure the priority of communications or signals relating to ships in distress. (Sec. 321*b*.)

Answer. All radio stations, including Government stations and stations on board foreign vessels when within the territorial waters of the United States, shall give absolute priority to radio communications or signals relating to ships in distress; shall cease all sending on frequencies which will interfere with hearing a radio communication or signal of distress, and, except when engaged in answering or aiding the ship in distress, shall refrain from sending any radio communications or signals until there is assurance that no interference will be caused with the radio communications or signals relating thereto, and shall assist the vessel in distress, so far as possible, by complying with its instructions.

111.04. *Question.* In what class of radio station and under what conditions is an operator permitted to adjust the transmitter for a maximum of radiation without regard to the interference produced? (Sec. 321*a*.)

Answer. The transmitting set in a radio station on shipboard may be adjusted in such a manner as to produce a maximum of radiation, irrespective of the amount of interference which may thus be caused, when such station is sending radio communications or signals of distress and radio communications relating thereto.

111.05. *Question.* In what cases may a transmitter on shipboard be adjusted to produce a maximum of radiation irrespective of the interference which may be caused? (Sec. 321.)

Answer. See answer to Question 111.04.

121.01. *Question.* What communications, if any, are not subject to the secrecy provisions of the Communications Act? (Sec. 605.)

Answer. Any radio communication broadcast, or transmitted by amateurs or others for the use of the general public, or relating to ships in distress.

121.02. *Question.* State in your own words the prohibition, if any, against the transmission of false calls and communications relating to distress. (Sec. 325*a*.)

Answer. No person within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto.

121.03. *Question.* State in your own words the law regarding the transmission of false or fraudulent signals of distress or communications relating thereto. (Sec. 325*a*.)

Answer. See answer to Question 121.02.

121.04. *Question.* **State in your own words the substance of the Communications Act that is provided to ensure the secrecy of radiograms. (Sec. 605.)**

Answer. The substance of the Act to ensure the secrecy of radiograms is that no person receiving or transmitting a radiogram, or in assisting in doing same, shall divulge or publish the existence, contents, substance, purport, effect, or meaning of the radiogram, except to the addressee, or his authorized agent, or those authorized to forward the message or handle same in a routine way, or on demand by competent lawful authorities, and furthermore, no one not entitled to it shall use the information obtained from the message for his own benefit or for the benefit of another. The penalty applied to violation of the secrecy laws is a fine not exceeding $10,000 or by imprisonment for a term of not more than 2 years, or both.

121.05. *Question.* **Does the Communications Act of 1934, as amended, contain any provision that prohibits the interception, use, and publication of radio communications? (Sec. 605.)**

Answer. Yes. See answer to Question 121.04.

131.01. *Question.* **What form of language if transmitted by an operator or other person makes him subject to the penal provisions of the Communications Act? (Sec. 326.)**

Answer. No person within the jurisdiction of the United States shall utter any obscene, indecent, or profane language by means of radio communication.

131.02. *Question.* **What provisions are made in the Communications Act to ensure intercommunication between stations in the mobile service? (Sec. 322.)**

Answer. Every land station open to general public service between the coast and vessels or aircraft at sea shall, within the scope of its normal operations, be bound to exchange radio communications or signals with any ship or aircraft station at sea; and each station on shipboard or aircraft at sea shall, within the scope of its normal operations, be bound to exchange radio communications or signals with any other station on shipboard or aircraft at sea or with any land station open to general public service between the coast and vessels or aircraft at sea: *Provided,* That such exchange of radio communication shall be without distinction as to radio systems or instruments adopted by each station.

131.03. *Question.* **Does the Federal Communications Commission have authority to issue a radio operator's license or permit to a citizen of a country other than the United States? (Sec. 303 [1].)**

Answer. No.

131.04. *Question.* **Has the master of a ship radiotelephone station the authority to forbid the transmission of a message by anyone on board? (Sec. 358.)**

Answer. Yes. The radio installation, the operators, the regulation of their watches, the transmission and receipt of messages, and the radio service of the ship except as they may be regulated by law or international agreement, or by rules and regulations made in pursuance thereof, shall in the case of a ship of the United States be under the supreme control of the master.

131.05. *Question.* Has the master of a ship station the authority to regulate the transmission and reception of messages on shipboard? (Sec. 358.)

Answer. Yes. See answer to Question 131.04.

131.06. *Question.* Under what conditions is the utterance or transmission of a false or fraudulent signal of distress or communications relating thereto permissible? (Sec. 325*a*.)

Answer. Under no conditions; it is never permissible. See answer to Question 121.02.

131.07. *Question.* Under what conditions is the utterance of obscene, indecent, or profane language by means of radio communication permissible? (Sec. 326.)

Answer. Under no conditions; it is never permissible. See answer to Question 131.01.

141.01. *Question.* What is the radiotelephony safety signal? (Art. 24 § 26 [2].)

Answer. In radiotelephony, the word SECURITY (corresponding to the French pronunciation of the word *sécurité* repeated three times, shall be used as the safety signal.

141.02. *Question.* Under what conditions may a mobile station, if necessary, disregard the General Radio Regulations (Cairo)? (Art. 24 [1].)

Answer. No provision of these Regulations shall prevent a mobile station in distress from using any means available to it for drawing attention, signaling its position, and obtaining help.

141.03. *Question.* What is the radiotelephony urgent signal? (Art. 24 § 22 [2].)

Answer. In radiotelephony the urgent signal shall consist of three transmissions of the expression PAN (corresponding to the French pronunciation of the word *panne*); it shall be transmitted before the call.

141.04. *Question.* What signals and messages are forbidden by international agreement? (Art. 22 § 1 [1].)

Answer. The transmission of unnecessary or unidentified signals or correspondence shall be forbidden to all stations.

141.05. *Question.* What precaution must an operator observe before proceeding with a transmission? (Art. 17 § 2 [1].)

Answer. Before transmitting, any station must keep watch over a sufficient interval to assure itself that it will cause no harmful interference with the transmissions being made within its range; if such interference is likely, the station shall await the first stop in the transmission which it may disturb.

141.06. *Question.* What does the receipt of the signal PAN transmitted by radiotelephony indicate? (Art. 24 § 22 [3].)

Answer. The urgent signal PAN shall indicate that the calling station has a very urgent message to transmit concerning the safety of a ship, an aircraft, or another vehicle, or concerning the safety of some person on board or sighted from on board.

141.07. *Question.* What should an operator do if he intercepts the word SECURITY repeated three times? (Art. 24 § 28 [2].)

Answer. All stations hearing the safety signal SECURITY must continue listening on the wave on which the safety signal has been sent until the message so announced has been completed; they must moreover keep silence on all waves likely to interfere with the message.

141.08. *Question.* Under what circumstances may the signal SECURITY be transmitted in radiotelephony? (Art. 24 § 26 [1].)

Answer. The safety signal SECURITY announces that the station is about to transmit a message concerning the safety of navigation or giving important meteorological warnings.

141.09. *Question.* The urgent signal sent by an aircraft and not followed by a message indicates what? (Art. 24 § 22 [4].)

Answer. In the aeronautical service, the urgent signal PAN shall be used in radiotelegraphy and radiotelephony to indicate that the aircraft transmitting it is in trouble and is forced to land, but that it is not in need of immediate help. This signal should, so far as possible, be followed by a message giving additional information.

141.10. *Question.* What obligation rests on an operator intercepting the signal PAN? (Art. 24 § 22 [5].)

Answer. The urgent signal PAN shall have priority over all other communications, except distress communications, and all mobile or land stations hearing it must take care not to interfere with the transmission of the message which follows the urgent signal.

151.01. *Question.* What procedure must be followed by a radio station receiving a distress call from a mobile station which is unquestionably in its vicinity? (Art. 24 § 11 [1].)

Answer. Stations of the mobile service which receive a distress message from a mobile station which is unquestionably in their vicinity must acknowledge receipt thereof at once. If the distress call has not been preceded by an auto-alarm signal, these stations may transmit this auto-alarm signal with the authorization of the authority responsible for the station, taking care not to interfere with the transmission of the acknowledgment of the receipt of said message by other stations.

151.02. *Question.* What essential information should be transmitted in a distress message? (Art. 24 § 6 [1].)

Answer. The distress call must be followed as soon as possible by the distress message. This message shall include the distress call followed by the name of the ship, aircraft, or the vehicle in distress, information regarding the position of the latter, the nature of the distress, the nature of the help requested, and any other further information which might facilitate this assistance.

151.03. *Question.* By what authority may the operator of a ship or aircraft station transmit a distress call or message? (Art. 24 § 8.)

Answer. The distress call and message shall be sent only by order of the master or person responsible for the ship, aircraft, or other vehicle carrying the mobile station.

151.04. *Question.* What is the international distress signal to be used in radiotelephony? (Art. 24 § 4 [1].)

Answer. In radiotelephony, the distress signal consists of the spoken expression MAYDAY (corresponding to the French pronunciation of the expression *m'aider*).

151.05. *Question.* What does the interception of the word MAYDAY transmitted by telephony announce? (Art. 24 § 4 [2].)

Answer. The distress signal MAYDAY shall announce that the ship, aircraft, or any other vehicle which sends the distress signal is threatened by serious and imminent danger and requests immediate assistance.

151.06. *Question.* Under the provisions of the treaty in transmitting distress messages in case of an emergency what radio waves may be used by aircraft stations? (Art. 24 § 3 [2].)

Answer. Any aircraft in distress must transmit the distress call on the watching wave of the land or mobile stations capable of helping it; when the call is addressed to stations of the maritime service, the waves to be used are the distress wave or watching wave of these stations.

151.07. *Question.* State the priority of radio communications in the mobile service. (Art. 26.)

Answer. The order of priority of radio communications in the mobile service shall be as follows:

1. Distress calls, distress messages, and distress traffic.
2. Communications preceded by an urgent signal.
3. Communications preceded by a safety signal.
4. Communications relative to radio direction-finding bearings.
5. Government radiotelegrams for which priority right has not been waived.
6. All other communications.

151.08. *Question.* What information must be contained in a distress message transmitted in an emergency, from a radio station aboard aircraft flying over land? (Art. 24 § 7 [3].)

Answer. As a general rule, an aircraft flying over land shall signal its position by the name of the nearest locality, its approximate distance from this point, accompanied, according to the case, by one of the words, North, South, East, or West, or, in some cases, words indicating intermediate directions.

151.09. *Question.* What information must be contained in a distress message? (Art. 24 § 6 [1].)

Answer. See answer to Question 151.02.

151.10. *Question.* After having sent its distress message, if an aircraft station is unable to signal its position, what procedure shall be followed to assist others in determining its approximate location? (Art. 24 § 6 [2].)

Answer. If an aircraft, in its distress message, is unable to signal its position, it shall endeavor after the transmission of the incomplete message to send its call long enough so that the radio direction-finding stations may determine its position.

161.01. *Question.* State at least two classes of stations which cannot be operated by the holder of a restricted radiotelephone operator permit. (R.&R. 13.61*e*.)

Answer. (1) A restricted radiotelephone operator permit is not valid for the operation of any of the various classes of broadcast stations other than a relay broadcast station.

(2) The permit is not valid for the operation of a coastal telephone station or a coastal harbor station other than in the Territory of Alaska.

(3) The permit is not valid for the operation of a ship station licensed to use type A-3 emission for communication with coastal telephone stations.

161.02. *Question.* **Under what conditions may the holder of a restricted radiotelephone operator's permit operate a station for which the permit is valid? (R.&R. 13.61*e*.)**

Answer. A restricted radiotelephone operator's permit authorizes the holder to operate any station while using type A-0, A-3, or A-4 emission, under the following conditions:

(1) Such operator is prohibited from making adjustments that may result in improper transmitter operation.

(2) The equipment is so designed that none of the operations necessary to be performed during the course of normal rendition of service may cause off-frequency operation or may result in any unauthorized radiation.

(3) Any needed adjustments of the transmitter that may affect the proper operation of the station are regularly made by or in the presence of an operator holding a first- or second-class license, either telephone or telegraph, who shall be responsible for the proper operation of the equipment.

161.03. *Question.* **State at least two classes of ship stations which the holder of a restricted radiotelegraph operator permit is prohibited from operating. (R.&R. 13.61*f* and R.&R. 2.53*a*, [2].)**

Answer. The exceptions which apply to a restricted radiotelegraph operator permit are

(1) The permit is not valid for the operation of a ship station licensed to use type A-3 emission for communication with coastal telephone stations.

(2) The license is not valid for the operation of a radiotelegraph station on board a vessel required by treaty or statute to be equipped with a radio installation.

161.04. *Question.* **Who is permitted to make adjustments or tests in the presence of the licensed operator responsible for the maintenance of the transmitter and under his responsibility for the proper operation of the equipment? (R.&R. 13.63.)**

Answer. The licensed operator responsible for the maintenance of a transmitter may permit other persons to adjust a transmitter in his presence for the purpose of carrying out tests or making adjustments requiring specialized knowledge or skill, provided that he shall not be relieved thereby from the responsibility for the proper operation of the equipment.

161.05. *Question.* **Within what period of time must any person receiving official notice of a violation of the terms of the Communications Act of 1934, as amended, Treaty, or Rules and Regulations of the Commission be required to answer such notice? (R.&R. 1.391.)**

Answer. Within a period of 3 days.

171.01. *Question.* **What is the obligation of an operator whose license or permit has been lost, mutilated, or destroyed? (R.&R. 13.71.)**

Answer. An operator whose license or permit has been lost, mutilated, or destroyed shall immediately notify the Commission. A sworn application for duplicate should be submitted to the office of issue embodying a statement attesting to the facts thereof. If a license has been lost, the applicant must state that reasonable search has been made for it, and further, that, in the event it be found, either the original or the duplicate will be returned for cancellation. The applicant must also give a statement of the service that had been obtained under the lost license.

171.02. *Question.* **How may the holder of a radiotelegraph or radiotelephone first- or second-class license indicate to representatives of the Commission that he is legally qualified to adjust equipment operated by holders of restricted radiotelephone operator permits? (R.&R. 13.75.)**

Answer. The holder of a radiotelegraph or radiotelephone first- or second-class license who is employed as a service and maintenance operator at stations operated by holders of restricted operator permits shall post at such stations his operator license or a verified statement from the Commission in lieu thereof.

171.03. *Question.* **How may an operator show proof of his legal qualifications to operate a radio transmitter? (R.&R. 2.52.)**

Answer. The original license of each station operator shall be posted at the place where he is on duty or kept in his possession in the manner specified in the regulations governing the class of station concerned.

171.04. *Question.* **What is an operator of a radio station, who has submitted his license for renewal or applied for a duplicate license, required to exhibit as his authority to continue operation of the station pending receipt of the license? (R.&R. 13.72.)**

Answer. When a duplicate operator license or permit has been requested, or request for renewal upon service has been made, the operator shall exhibit in lieu thereof a signed copy of the application for duplicate, or renewal, which has been submitted by him.

171.05. *Question.* **What is the holder of a radiotelegraph or radiotelephone first- or second-class license, who is employed as a service and maintenance operator at stations operated by holders of restricted operator permits, obligated to post at the stations? (R.&R. 13.75.)**

Answer. See answer to Question 171.02.

181.01. *Question.* **How may corrections be made in a log? (R.&R. 2.57.)**

Answer. Any necessary correction may be made only by the person originating the entry, who shall strike out the erroneous portion, initial the correction made, and indicate the date of correction.

181.02. *Question.* **Is it lawful to erase an entry made in a station log? (R.&R. 2.57.)**

Answer. No log or portion thereof shall be erased, obliterated, or willfully destroyed within the period of retention provided by the rules.

181.03. *Question.* **What are the Commission's requirements with regard to the retention of a radio station log? (R.&R. 2.54.)**

Answer. Logs of a radio station, when required elsewhere in the rules and regulations to be made or kept, shall be retained by the licensee for a period of 1 year unless otherwise provided by the rules governing the particular service or class of station concerned.

181.04. ***Question.*** **How long must the licensee retain a station log which involves communications incident to a disaster? (R.&R. 2.54.)**

Answer. Logs involving communications incident to a disaster, or which include communications incident to or involved in an investigation by the Commission and concerning which the licensee has been notified, shall be retained by the licensee until specifically authorized in writing by the Commission to destroy them.

181.05. ***Question.*** **What is the Commission's rule with regard to rough logs? (R.&R. 2.58.)**

Answer. Rough logs may be transcribed into condensed form, but in such cases the original log or memoranda and all portions thereof shall be preserved and made a part of the complete log.

191.01. ***Question.*** **What procedure should one follow if he desires to resist an order of suspension of his operator's license or permit? (Sec. 303*m* and R.&R. 1.411 and 1.412.)**

Answer. The operator in question may make written application to the Commission at any time within 15 days for a hearing upon an order of suspension of his operator's license or permit. The suspension of the operator's license is not effective until the notice is actually received by him, and from that time he is given 15 days in which to mail the application for a hearing. In the event that physical conditions prevent mailing of the application at the expiration of the 15-day period, the application shall then be mailed as soon as possible thereafter, accompanied by a satisfactory explanation of the delay.

191.02. ***Question.*** **What is the responsibility of a licensee of a radio station with respect to permitting it to be inspected by representatives of the Commission? (R.&R. 2.48.)**

Answer. The licensee of any radio station shall make the station available for inspection by representatives of the Commission at any reasonable hour and under the regulations governing the class of station concerned.

191.03. ***Question.*** **Who is responsible for control of distress traffic? (Art. 24 § 14 and R.&R. 2.60.)**

Answer. The control of distress traffic shall devolve upon the mobile station in distress, or upon the mobile station which by application of the provisions governing retransmission of a distress message has sent the distress call. These stations may delegate the control of the distress traffic to another station.

Note. See answer to Question 101.01 for provisions governing the *retransmission of distress messages.*

191.04. ***Question.*** **Are logs subject to inspection by representatives of the Commission? (R.&R. 2.55.)**

Answer. Yes, logs shall be made available upon request by an authorized representative of the Commission.

191.05. ***Question.*** **By whom may the log of a radio station be kept? (R.&R. 2.55.)**

Answer. Each log shall be kept by the person or persons competent to do so, having actual knowledge of the facts required, who shall sign the log when starting duty and again when going off duty.

101.01. ***Question.*** **Under what conditions may a distress message be retransmitted? (R.&R. 2.61.)**

Answer. Any station which becomes aware that a mobile station is in distress may transmit the distress message in the following cases:

(*a*) When the station in distress is not itself in a position to transmit the message.

(*b*) In the case of mobile stations, when the Master or the person in charge of the ship, aircraft, or other vehicle carrying the station which intervenes believes that further help is necessary.

(*c*) In the case of other stations, when directed to do so by the station in control of distress traffic or when it has reason to believe that a distress call which it has intercepted has not been received by any station in a position to render aid.

101.02. ***Question.*** **What tolerance in operating power is permissible under normal circumstances? (R.&R. 2.80.)**

Answer. The operating power of all radio stations shall be maintained within the following tolerance of the assigned power:

1. When the maximum power only is specified, the operating power shall not be greater than necessary to carry on the service and in no event more than 5 per cent above the maximum power specified.
2. When the exact power is specified, the operating power shall not be more than 5 per cent above or less than 10 per cent below such power.

101.03. ***Question.*** **Under what conditions may a station be operated in a manner other than that specified in the station license? (R.&R. 2.63.)**

Answer. **Operation during emergency.** The licensee of any station, except amateurs, may, during a period of emergency in which the normal communication facilities are disrupted as a result of a hurricane, flood, earthquake, or similar disaster, utilize such station for emergency communication service in communicating in a manner other than that specified in the station license, provided (1) that as soon as possible after the beginning of such emergency use notice be sent to the Commission in Washington, D. C., and to the Inspector in Charge of the district in which the station is located, stating the nature of the emergency and the use to which the station is being put, and (2) that the emergency use of the station shall be discontinued as soon as substantially normal communication facilities are again available and the Commission in Washington, D. C., and the Inspector in Charge be notified immediately when such special use of the station is terminated. The Commission may at any time order the discontinuance of such service.

101.04. ***Question.*** **What is the Commission's rule with respect to measurement of the radio station frequency? (R.&R. 2.75.)**

Answer. The licensee of each station shall provide means for the measurement of the station frequency. The measurement of the station frequency shall be made by a means independent of the frequency control of the transmitter and shall be conducted in accord with the regulations governing the class of station concerned.

101.05. ***Question.*** **When may operation be resumed after a station has been notified to cease transmission because of interference to distress traffic? (R.&R. 2.62.)**

Answer. No station having been notified to cease operation shall resume operation on frequency or frequencies which may cause interference until notified by the station issuing the original notice that the station involved will not interfere with distress traffic as it is then being routed or until receipt of a general notice that the need for handling distress traffic no longer exists.

ELEMENT 2

BASIC THEORY AND PRACTICE

2.1. *Question.* By what other expression may a "difference of potential" be described?

Answer. Expressions commonly used instead of "difference of potential" are as follows: electromotive force; e.m.f.; voltage; voltage drop; *IR* drop; fall of potential.

2.2. *Question.* By what other expression may an "electric current flow" be described?

Answer. Electron flow. Another convenient expression for electric current flow is *amperage.*

2.3. *Question.* Which factors determine the amplitude of the e.m.f. induced in a conductor which is cutting magnetic lines of force?

Answer. The factors are as follows: number of lines of force, or flux density; rate of cutting the lines; angle at which the conductor cuts across or through the flux; length of the conductor.

2.4. *Question.* Name four methods by which an electrical potential may be generated.

Answer. (1) Dynamic. *Example:* by mechanical motion, as in generators. (2) Chemical. *Example:* by chemical action, as in batteries. (3) Friction. *Example:* static electricity. (4) Thermal. *Example:* by heat produced when current flows across a thermal junction composed of two dissimilar metals.

2.5. *Question.* If the diameter of a conductor of given length is doubled, how will the resistance be affected?

Answer. The resistance will be decreased four times, or will be one-fourth of the original resistance.

Discussion. This statement is true because the cross-sectional area of the conductor varies directly as the diameter squared, or $A \propto d^2$, and the resistance of the conductor is inversely proportional to the cross-sectional area. Note that the sign $\propto$ means "varies as."

2.6. *Question.* If the value of a resistance, to which a constant e.m.f. is applied, is halved, what will be the resultant proportional power dissipation?

Answer. The resultant power dissipation will be two times greater, or doubled.

Discussion. This deduction follows because reducing the resistance one-half results in twice the current flow and with the voltage unchanged the wattage will be doubled.

2.7. *Question.* What method of connection should be used to obtain the maximum no-load output voltage from a group of similar cells in a storage battery?

Answer. Series connection.

2.8. ***Question.*** **What is the sum of all voltage drops around a simple d-c series circuit, including the source?**

Answer. Zero, by Kirchhoff's second law.

Discussion. The voltage drops around a simple d-c series circuit add up algebraically to equal *zero,* since the voltage drop in the source or generator is considered a negative value, whereas the voltage drops in the load circuit are positive values.

2.9. ***Question.*** **What method of connection should be used to obtain the maximum short-circuit current from a group of similar cells in a storage battery?**

Answer. Parallel connection.

2.10. ***Question.*** **If the value of a resistance, across which a constant e.m.f. is applied, is doubled, what will be the resultant proportional power dissipation?**

Answer. One-half of the original power dissipation.

2.11. ***Question.*** **(*a*) Name four materials which are good insulators at radio frequencies. (*b*) Name four materials which are not good insulators at radio frequencies but which are satisfactory for use at commercial power frequencies.**

Answer. (*a*) Isolantite, micalex, steatite, pyrex. (*b*) Glass, rubber, fiber, porcelain.

2.12. ***Question.*** **Explain the factors which influence the resistance of a conductor.**

Answer. Kind of material; cross-sectional area; length; temperature.

2.13. ***Question.*** **What effect does the cross-sectional area of a conductor have upon its resistance per unit length?**

Answer. The resistance, R, is inversely proportional to the cross-sectional area, A, or $R \propto 1/A$. The sign $\propto$ means *"varies as."*

Discussion. For example, if the cross-sectional area of a conductor of given length is made four times as great its resistance will be lowered to one-fourth of the original value.

Another way of stating this relationship is that the resistance per unit length varies directly as the reciprocal of the cross-sectional area. See Question 2.5.

2.14. ***Question.*** **Name five conducting materials in the order of their conductivity.**

Answer. Silver, copper, aluminum, pure iron, and lead.

2.15. ***Question.*** **What effect does a change in the dielectric constant of a condenser dielectric material have upon the capacitance of a condenser?**

Answer. The capacitance, C, varies directly as the dielectric constant, k. Since $C \propto k$, then increasing the dielectric constant will increase the capacitance in the same proportion, and likewise, decreasing k will decrease C in the same proportion.

2.16. ***Question.*** **Explain the effect of increasing the number of plates upon the capacitance of a condenser.**

Answer. Increasing the number of plates will increase the effective area of the plates, which increases the capacitance.

2.17. ***Question.*** **State the formula to determine the capacitive reactance of a condenser.**

Answer. $X_C = \frac{1}{2\pi fC}$ ohms. This is the basic form with C in farads.

Discussion. Also, since $2\pi f$ may be expressed by the symbol omega, ω, the formula may be written $X_C = \frac{1}{\omega C}$.

The following formula is of more practical use because capacitance, most generally expressed in microfarads, may be inserted directly without converting microfarads to farads.

$$X_C = \frac{10^6}{2\pi fC} \text{ ohms,} \quad \text{where } C \text{ is in microfarads.}$$

2.18. ***Question.*** **If the specific inductive capacity of a condenser dielectric material between the condenser plates were changed from 1 to 2, what would be the resultant change in capacitance?**

Answer. Capacitance would be doubled.

2.19. ***Question.*** **State the formula for determining (*a*) the quantity or charge of a condenser, and (*b*) the energy stored in a condenser.**

Answer. (*a*) $Q = C \times E$, where C is in farads, Q in coulombs, and E in volts. The following formula is used where C is given in microfarads,

$$Q = C \times E \times 10^{-6}.$$

(*b*) The formula for energy stored is (W) Joules $= \frac{1}{2}CE^2$.

2.20. ***Question.*** **Neglecting temperature coefficient of resistance and using the same gauge of wire and the same applied voltage in each case, what would be the effect, upon the field strength of a single layer solenoid, of a small increase in the number of turns?**

Answer. A small increase in the number of turns would produce a decrease in field strength with the same voltage applied.

Assuming a constant applied d-c voltage, the field strength at the center of the solenoid varies inversely with the number of turns. Hence, a small increase in the number of turns would produce a decrease in field strength, which applies to the question as stated. In the event the current remained constant, or practically unchanged, and the length of the coil was not affected then an increase in the number of turns would produce an increase in field strength.

Discussion. A discussion on this question for both **a.c.** and **d.c.** follows: As a basis for discussion we shall use the formula for the field intensity at the middle of a solenoid. This formula applies when the length is much larger than the diameter, that is, a long solenoid.

$$H = \frac{0.4\pi NI}{l},$$

where N = number of turns,
I = current in amperes,
l = length in centimeters,
H = field strength in gilberts per centimeter.

The formula for H is again expressed for the two conditions, namely, when using the initial number of turns, and after change, or

$H_1 = \frac{0.4\pi N_1 I_1}{l_1}$ and $H_2 = \frac{0.4\pi N_2 I_2}{l_2}$, where subscript 1 indicates the initial condition and subscript 2 is the condition after change; or

$$\frac{H_2}{H_1} = \frac{N_2 I_2 l_1}{N_1 I_1 l_2} \qquad [1]$$

Now two cases are discussed, one giving the d-c solution and the other the a-c solution.

Case 1. **D-C Solution:**

$$\frac{I_2}{I_1} = \frac{\dfrac{E}{\dfrac{N_2}{N_1}R_1}}{\dfrac{E}{R_1}} = \frac{N_1}{N_2}$$ (Resistance assumed to vary as the number of turns, N)

$$\frac{l_1}{l_2} = \frac{l_1}{\dfrac{N_2}{N_1}l_1} = \frac{N_1}{N_2}$$ (Length assumed to vary as number of turns, N)

Substituting in Equation 1

$$\therefore \frac{H_2}{H_1} = \frac{N_2}{N_1} \times \frac{N_1}{N_2} \times \frac{N_1}{N_2} = \frac{N_1}{N_2}$$

Assuming a constant applied d-c voltage, the field strength, H, at the center of a solenoid varies inversely with the number of turns. Hence, a small increase of the number of turns would cause a decrease in H. It should be noted that the foregoing applies to the problem as stated. In the event the current remained constant and the length of the coil was not affected, then an increase in the number of turns would cause an increase of H in accordance with $H_2/H_1 = N_2/N_1$.

Case 2. **A-C Solution:**

$$\frac{I_2}{I_1} = \frac{\dfrac{E}{\omega\left(\dfrac{N_2}{N_1}\right)^2 L_1}}{\dfrac{E}{\omega L_1}} = \left(\frac{N_1}{N_2}\right)^2$$ (Reactance predominating and inductance, L, varying as N^2)

$$\frac{l_1}{l_2} = \frac{l_1}{\left(\dfrac{N_2}{N_1}\right)l_1} = \frac{N_1}{N_2}$$ (Length assumed to vary as N)

Substituting in Equation 1

$$\frac{H_2}{H_1} = \frac{N_2}{N_1}\left(\frac{N_1}{N_2}\right)^2 \frac{N_1}{N_2} = \left(\frac{N_1}{N_2}\right)^2$$

Assuming a constant applied a-c voltage, the field strength, H, at the center of the solenoid varies inversely as the square of the number of turns. Hence, an increase in the number of turns, as stated, will cause a considerable decrease in H. (Again it should be noted that if the current rather than the voltage is held constant and further, if the length of the coil is not affected, then an increase in the number of turns will produce an increase in H in accordance with $H_2/H_1 = N_2/N_1$.)

2.21. *Question.* How may a magnetic compass be affected when placed within a coil carrying an electrical current?

Answer. The compass needle will arrange itself at right angles to the current flow and line up along the axis of the coil with the north pole pointing toward the south pole end of the coil.

2.22. ***Question.*** **What materials may be used for shielding a radio-frequency magnetic field?**

Answer. Aluminum and copper are two commonly used materials. Other materials, such as brass and white metal, having low resistance characteristics are also found in use.

2.23. ***Question.*** **What is the advantage to be gained by "bank winding" an inductance?**

Answer. Reduction of distributed capacitance.

2.24. ***Question.*** **Which factors influence the direction of magnetic lines of force generated by an electromagnet?**

Answer. Direction of the current flow through the turns and the manner in which the turns are wound.

2.25. ***Question.*** **Explain the meaning of and factors which determine the "Q" or "figure of merit" of an inductance.**

Answer. The "Q" value of an inductance (that is, an inductance coil) is the ratio of apparent inductive reactance to effective or a-c resistance. The expression for Q is

$$Q = \frac{X_L}{R_e} = \frac{2\pi f L}{R_e},$$

where f = frequency in cps (cycles per second),
L = inductance in henrys,
R_e = effective high-frequency resistance in ohms.

2.26. ***Question.*** **Define the term "permeability."**

Answer. "Permeability" is the specific conductivity of a substance for magnetic flux, the magnetic conductivity of air being used as a standard basic unit for comparison. Permeability from a practical viewpoint may be considered as the relative ease with which magnetic lines can be set up in a magnetic material in comparison with the same lines being set up in air.

2.27. ***Question.*** **What unit is used in expressing the alternating-current impedance of a circuit?**

Answer. Ohm.

2.28. ***Question.*** **What is the unit of resistance?**

Answer. Ohm.

2.29. ***Question.*** **Explain the meaning of the prefix "micromicrofarad."**

Answer. The prefix "micromicro" means one-millionth of one-millionth part of a farad. A farad multiplied by 10^{-12} expresses the same thing.

2.30. ***Question.*** **What is the unit of capacitance?**

Answer. Farad.

2.31. ***Question.*** **What single instrument may be used to measure (*a*) Electrical resistance? (*b*) Electrical power? (*c*) Electrical current? (*d*) Electromotive force?**

Answer. (*a*) Ohmmeter. (*b*) Wattmeter. (*c*) Ammeter. (*d*) Voltmeter.

2.32. **Question. Define the term "residual magnetism."**

Answer. "Residual magnetism" is the magnetism remaining in a magnetized substance after the magnetizing force has been removed.

2.33. **Question. What is the unit of electrical power?**

Answer. Watt.

2.34. **Question. What is the unit of conductance?**

Answer. Mho.

2.35. **Question. What is the unit of inductance?**

Answer. Henry.

2.36. **Question. What is the meaning of the prefix "kilo"?**

Answer. "Kilo" means 1000, or one thousand times the quantity following the prefix. For example: One kilowatt equals 1000 watts.

2.37. **Question. What is the meaning of the prefix "micro"?**

Answer. "Micro" means one-millionth part of a quantity, or 10^{-6}.

2.38. **Question. What is the meaning of "power factor"?**

Answer. "Power factor" is the ratio of the active power to the apparent power.

The apparent power (volts × amperes) must be multiplied by the power factor in order to determine the active or true power.

The value of the power factor is indicated by the cosine of the phase angle formed when current and voltage are not in phase; written "cos θ." The resistance divided by the impedance of an a-c circuit equals the power factor, thus p.f. $= R/Z$.

2.39. **Question. What is the meaning of the prefix "meg"?**

Answer. "Meg" means 1,000,000, or one million times the quantity following the prefix. For example, one million ohms equals one megohm.

2.40. **Question. Define the term "conductance."**

Answer. Conductance, G, is the reciprocal of resistance, R, or $G = 1/R$. The term indicates that property of a conductor which allows a current to flow; and since different conductors permit different degrees of freedom to the current, the conductors can be compared as to their conductivity. In a practical sense conductance indicates the relative ease with which a conductor will pass an electric current and is, therefore, the opposite to the meaning of resistance.

2.41. **Question. What instrument is used to measure current flow?**

Answer. Ammeter. An ammeter designed to indicate small currents is called a *milliammeter,* and one for very small currents a *microammeter.*

2.42. **Question. Define the term "decibel."**

Answer. The unit decibel is used to express the logarithmic ratio between two electrical power levels or two sound power levels, or it may be used to express the ratio between two voltages or two currents acting in the same or equal impedances.

Note that only a ratio or comparison between two intensities or values is indicated and not their actual values. The first formula below gives the number of decibels, *db,* corresponding to the ratio between two amounts of power, P_1 and P_2, while the second and third formulas give the number of decibels which would indicate the ratio of the relative values, respectively, of two voltages and two currents. Note that n is the number of decibels denoting these ratios.

$$(1)\ n = 10 \log_{10} \frac{P_1}{P_2}\ \text{db} \qquad (2)\ n = 20 \log_{10} \frac{E_1}{E_2}\ \text{db} \qquad (3)\ n = 20 \log_{10} \frac{I_1}{I_2}\ \text{db}$$

2.43. *Question.* What is meant by "ampere turns"?

Answer. "Ampere turns" is a practical term used to indicate a magnetomotive force set up by a current flowing through the turns of a coil as given by the following expression where N is the number of turns and I is the current, or

$$\text{Ampere turns} = N \times I$$

2.44. *Question.* Define the term "inductance."

Answer. "Inductance" is the property of an electric circuit, or of two neighboring circuits, which determines the electromotive force induced in one of the circuits by a change of current in either of them. (A.I.E.E. definition.)

Discussion. Another term, "self inductance," is closely related to the term "inductance." The definition of "self inductance" is as follows: "Self inductance" is the property of an electric circuit which determines, for a given rate of change of current in the circuit, the electromotive force induced in the same circuit. (A.I.E.E. definition.)

2.45. *Question.* Define the term "coulomb."

Answer. A "coulomb" is the quantity of electricity which passes any section of an electric circuit in 1 second when the current is 1 ampere. Hence, a coulomb is a unit quantity of electricity equal to 1 ampere per second. Defining a coulomb in terms of an electron, 1 coulomb equals 6.28 times 10^{18} electrons.

2.46. *Question.* Define the term "power factor."

Answer. The term "power factor" indicates the phase difference, or phase angle, between current and voltage acting in a circuit containing reactance elements. In other words, the power factor is the cosine of the phase angle because the apparent power, or $E \times I$, must be multiplied by this factor to obtain the true power. Also, since the power factor is always unity, or one (1), in a purely resistive circuit and less than one with reactive elements, the ratio of the resistance to the impedance of an a-c circuit is the power factor, or

$$\text{p.f.} = \frac{R}{Z}$$

2.47. *Question.* What is the unit of magnetomotive force?

Answer. The unit of magnetomotive force is the "gilbert" in the *CGS* electromagnetic system, or the "ampere-turn" in the practical system.

$$1 \text{ ampere-turn} = 1.257 \text{ gilberts}$$

2.48. *Question.* Express 1 horsepower in watts.

Answer. One horsepower is equal to 746 watts.

2.49. *Question.* State the three ordinary mathematical forms of Ohm's law.

Answer. The relationship between voltage, current, and resistance may be expressed in three different forms:

$$(1)\ I = \frac{E}{R} \qquad (2)\ E = I \times R \qquad (3)\ R = \frac{E}{I}$$

2.50. *Question.* State Ohm's law.

Answer. The current in a circuit is directly proportional to the voltage applied and inversely proportional to the resistance of the circuit.

2.51. *Question.* If a vacuum tube having a filament rated at one-quarter ampere and 5 volts is to be operated from a 6-volt battery, what is the value of the necessary series resistor?

Answer. 4 ohms.

Solution: The series resistor must drop the voltage 1 volt and the current through it is the same as the filament. Applying the known values in Ohm's law to find resistance, we have

$$R = \frac{E}{I} = \frac{1}{0.25} = 4 \text{ ohms}$$

2.52. *Question.* If the voltage applied to a circuit is doubled and the resistance of the circuit is increased to three times its former value, what will be the final current value?

Answer. The final current value will be two-thirds of the initial current value.

Solution: The proportion expressed by Ohm's law which gives this answer is the formula used to find current. Then multiply E by 2 (that is, doubled) and multiply R by 3, or

$$I = \frac{E}{R} = \frac{2 \times E}{3 \times R}$$

2.53. *Question.* If a relay is designed to operate properly from a 6-volt d-c source, and if the resistance of the winding is 120 ohms, what value of resistance should be connected in series with the winding if the relay is to be used with a 120-volt d-c source?

Answer. 2,280 ohms.

Solution: The series resistor must drop the voltage 114 volts, or the difference between the new line voltage, 120 volts, and the rated operating voltage of the relay, 6 volts. Also, this resistor must pass the same current as the relay is rated to take, which is found by using $I = E/R$, or 6/120, or 0.05 ampere. Having found the required voltage drop across the resistor, 114 volts, and the current through it, 0.05 ampere, the value of this resistor then will be given by using $R = E/I$, or 114/0.05, or 2,280 ohms.

2.54. *Question.* What should be the minimum power dissipation rating of a resistor of 20,000 ohms to be connected across a potential of 500 volts?

Answer. The actual power dissipation would be 12.5 watts, but such a resistor would be rated higher in practice, or about 50 watts, to allow for a good margin of safety and to ensure long life. In general, resistors are operated at about 25 per cent of their maximum watt dissipation rating and at about 75 per cent of their maximum current carrying capacity rating.

Solution: First find the current, or $I = E/R$, $500 \div 20{,}000$, or 0.025 ampere. Now insert the I and E values in the watt formula, or $W = I \times E$, or 0.025×500, or 12.5 watts.

2.55. *Question.* If resistors of 5, 3, and 15 ohms are connected in parallel, what is the total resistance?

Answer. Total resistance is 1⅔ ohms, or 1.666 ohms.

Solution: Apply the formula: $\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \cdots$

$$\frac{1}{R_{\text{total}}} = \frac{1}{5} + \frac{1}{3} + \frac{1}{15} = \frac{3}{15} + \frac{5}{15} + \frac{1}{15} = \frac{9}{15} = \frac{3}{5}$$

Therefore, by inverting $1/R$ to $R/1$, we have

$$\frac{R}{1} = \frac{5}{3} = 1\tfrac{2}{3} \text{ ohms}$$

2.56. *Question.* What is the maximum rated current carrying capacity of a resistor marked "5,000 ohms, 200 watts"?

Answer. The maximum rating is 0.2 ampere.

Solution: Since $W = I^2R$, then $I^2 = \frac{W}{R}$, or $I = \sqrt{\frac{W}{R}}$. Now substituting known values for W and R we get

$$I = \sqrt{\frac{200}{5{,}000}} = \sqrt{0.04} = 0.2 \text{ ampere}$$

2.57. *Question.* Show how you would use a wave-trap to exclude an undesired radio signal from a receiver.

Answer. Figure 1 shows two types of wave-traps.

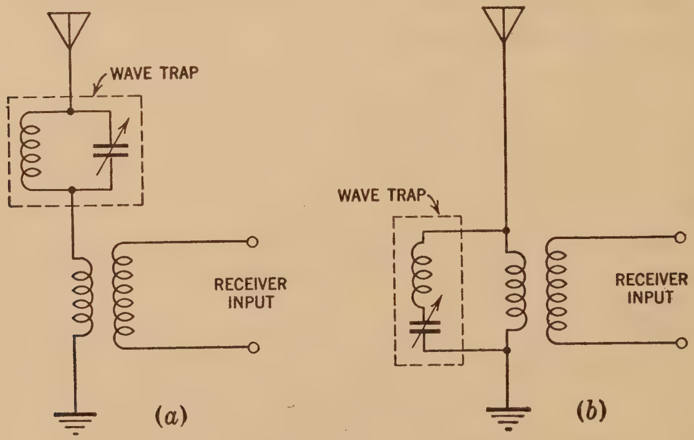


FIG. 1. Wave-traps for input to receiver.

2.58. *Question.* A milliammeter with a full-scale deflection of 1 milliampere and having a resistance of 25 ohms was used to measure an unknown current by shunting the meter with a four (4) ohm resistor. It then read 0.4 milliampere. What was the unknown current value?

Answer. 2.9 milliamperes.

Solution: The proportion of current in the meter compared to the shunt is 25 ÷ 4, or 6.25 times more current in the shunt. Hence, the current in the shunt on full-scale deflection will be 1×6.25, or 6.25 milliamperes, and the total current through both meter and shunt on full-scale deflection will be $1 + 6.25$, or 7.25 milliamperes. If the meter now reads only 0.4 of its full-scale value the current in the shunt also will be 0.4 of its former value, and therefore the new total current taken by meter and shunt will be $7.25 \times 0.4 = 2.9$ milliamperes.

2.59. ***Question.*** **What will be the heat dissipation, in watts, of a resistor of 20 ohms having a current of one-quarter (0.25) ampere passing through it?**

Answer. 1.25 watts.

Solution: Use the power formula:

$$W = I^2R = 0.25^2 \times 20 = 0.0625 \times 20 = 1.25 \text{ watts.}$$

2.60. ***Question.*** **If two 10-watt, 500-ohm resistors are connected in parallel, what are the power dissipation capabilities of the combination?**

Answer. 20 watts. The total power dissipating capabilities of resistors in parallel or series are equal to the sum of their individual ratings.

2.61. ***Question.*** **What is the formula used to determine the total capacitance of three or more capacitors connected in series?**

Answer.

$$C_{\text{total}} = \frac{1}{\dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}, \text{ etc.}}$$

2.62. ***Question.*** **What is the formula for determining the capacitive reactance of a condenser?**

Answer.

$$X_C = \frac{1}{2\pi fC},$$

where X_C = capacitive reactance in ohms,
f = frequency in cycles per second,
C = capacitance in farads.

Where the capacitance is given in microfarads with the other units the same as indicated above, the formula is written as follows:

$$X_C = \frac{10^6}{2\pi fC}$$

2.63. ***Question.*** **If condensers of 1, 3, and 5 microfarads are connected in parallel, what is the total capacitance?**

Answer. 9 micromicrofarads. In parallel combination the total capacitance is equal to the sum of the individual capacitors.

2.64. ***Question.*** **What is the formula used to determine the total capacitance of three or more condensers connected in parallel?**

Answer.

$$C_{\text{total}} = C_1 + C_2 + C_3, \text{ etc.}$$

2.65. ***Question.*** **If condensers of 5, 3, and 7 microfarads are connected in series, what is the total capacitance?**

Answer. 1.478 microfarads.

Solution: For simplicity in writing the formula and illustrating how the problem may be worked out we use first the reciprocal of the total capacitance, or $1/C_{\text{total}}$, and then invert both sides of the equation to find the total, thus

$$\frac{1}{C_{\text{total}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{5} + \frac{1}{3} + \frac{1}{7} = \frac{21}{105} + \frac{35}{105} + \frac{15}{105} = \frac{71}{105}$$

Since $\frac{1}{C_{\text{total}}} = \frac{71}{105}$, then by inverting both members we get

$$C_{\text{total}} = \frac{105}{71} = 1.478 \text{ microfarads}$$

2.66. ***Question.*** **The charge in a condenser is stored in what portion of the condenser?**

Answer. The charge in a condenser is stored in the dielectric and is given by

$Q = C \times E$, where C = capacitance in farads,
E = voltage in volts,
Q = charge in coulombs.

In turn

$C = k \times C_{\text{air}}$, where C_{air} = condenser capacitance with air as a dielectric,
k = dielectric constant of material between plates.

2.67. ***Question.*** **Having available a number of condensers rated at 400 volts and 2 microfarads each, how many of these condensers would be necessary to obtain a combination rated at 1,600 volts and 1.5 microfarads?**

Answer. 12 condensers. This combination would consist of three parallel branches with each branch consisting of 4 condensers in series.

2.68. ***Question.*** **The voltage drop across an individual condenser of a group of condensers in series across a source of potential is proportional to what factors?**

Answer. The voltage drop across the individual condenser is inversely proportional to its capacitance; also, the voltage drop across the individual condenser is directly proportional to the voltage applied across the condenser combination in series.

2.69. ***Question.*** **What factors determine the charge stored in a condenser?**

Answer. The factors are the capacitance of the condenser and the impressed voltage across it. Apply formula $Q = CE$.

2.70. ***Question.*** **Given two identical mica condensers of 0.1 microfarad capacity each. One of these is charged to a potential of 125 volts and disconnected from the charging circuit. The charged condenser is then connected in parallel with the uncharged condenser. What voltage will appear across the two condensers connected in parallel?**

Answer. 62.5 volts.

Explanation. In any combination of capacitances in parallel, the voltage for each is the same. When one is charged and then connected to others the total charge remains unchanged, assuming no losses.

Case 1: For the given problem with only one condenser charged and the capacitance equal to 0.1 microfarad.

$$Q = CE_1 = 0.1 \times 10^{-6} \times 125 = 12.5 \times 10^{-6} \text{ coulombs}$$

Case 2: In the second case where the charged condenser is connected to the uncharged one and the capacitance is doubled, or 0.2 microfarad, for this parallel connection.

$$Q = 12.5 \times 10^{-6}$$

$$C = 0.2 \times 10^{-6}$$

Since $Q = CE_2$ and substituting for Q and C from above

$$12.5 \times 10^{-6} = 0.2 \times 10^{-6} E_2$$

$$E_2 = \frac{12.5 \times 10^{-6}}{0.2 \times 10^{-6}} = 62.5 \text{ volts}$$

2.71. *Question.* State the formula which is used in determining the reactance of an inductance.

Answer.

$$X_L = 2\pi fL, \text{ where } L = \text{inductance in henrys.}$$

2.72. *Question.* What will be the inductive reactance of a 30-henry choke coil at 100 cycles?

Answer. 18,840 ohms.

Solution: Insert known values in formula

$$X_L = 2\pi fL$$

$$= 6.28 \times 100 \times 30 = 18{,}840 \text{ ohms}$$

2.73. *Question.* What is the effect of adding an iron core to an air core inductance?

Answer. The inductance of the coil will be increased. It is possible to obtain a large inductance with a coil of comparatively small physical dimensions by the use of an iron core because the iron greatly increases the number of lines of force, or flux, set up by a given magnetomotive force.

2.74. *Question.* What will be the effect of a shorted turn in an inductance?

Answer. A shorted turn greatly increases the effective resistance. This is particularly true at high frequencies. The inductance is reduced in this case. By consequence of these two effects the coil Q is vastly reduced. At high frequencies C is reflected into the coil owing to the shorted turn affecting the distributed capacitance. Hence, the L, C, and R values of the coil are changed. A shorted turn would cause overheating with possible burnout if a large current were handled by the coil.

2.75. *Question.* What is the relationship between the number of turns and the inductance of a coil?

Answer. The inductance, L, is proportional to the number of turns squared, N^2.

2.76. *Question.* Define the term "reluctance."

Answer. "Reluctance" applies to a magnetic circuit and is the opposition to the establishment of magnetic lines of force, or magnetic flux.

Discussion. For a given medium **reluctance** is defined by:

$$\mathcal{R} = \frac{l}{\mu A},$$

where l = length of path in cm.,
A = area of cross section in sq. cm.,
μ = permeability of medium,
$\mathcal{R}$ = reluctance in oersteds.

Reluctance in a magnetic circuit is analogous to resistance in the Ohm's law circuit. This is apparent from the following:

$$\phi = \frac{MMF}{\mathcal{R}},$$

where MMF = magnetomotive force in gilberts,
$\mathcal{R}$ = reluctance in oersteds,
ϕ = magnetic flux in maxwells.

It is also to be noted that $MMF = 0.4 \times N \times I$, where N is the number of turns, I the current in amperes, and MMF the magnetomotive force in gilberts.

2.77. *Question.* What are some of the factors which determine the "figure of merit" or "Q" of an inductance?

Answer. Some of the factors are frequency, inductance, and effective high-frequency resistance as suggested by the "Q" formula. Other factors in general which determine the "Q" of a coil are the geometrical form of the coil; its distributed capacity; the kind of material used in the winding, giving it a certain ohmic resistance; type of winding; the influence of any materials within the field of the coil, such as coil forms possessing dielectric losses; coupled circuits which effect R; nature of the core, whether air or ferromagnetic.

Discussion. The figure of merit, or Q, of an inductance is given by the ratio of reactance, X, to resistance, R, or

$$Q = \frac{X}{R} = \frac{\omega L}{R},$$

where $\omega = 2\pi f$,
f = frequency in cps,
L = inductance in henrys,
R = effective resistance in ohms.

In regard to the effective resistance, R, there are three considerations: In air core coils this is just the a-c resistance of the winding; in ferromagnetic coils it includes the influence of the eddy current and hysteresis losses; and in a coil coupled to any circuit, then R must include effects of this coupling.

2.78. *Question.* State the formula for determining the resonant frequency of a circuit when the inductance and capacitance are known.

Answer.

$$f = \frac{1}{2\pi\sqrt{LC}},$$

where f = frequency in cps,
L = inductance in henrys,
C = capacitance in farads.

2.79. ***Question.*** **What is the formula for determining the power in a d-c circuit when the voltage and resistance are known?**

Answer.

$P = \frac{E^2}{R}$, where P = power in watts,
E = e.m.f. in volts,
R = resistance in ohms.

2.80. ***Question.*** **What is the formula for determining the power in a d-c circuit when the current and the resistance are known?**

Answer.

$P = I^2R$, where P = power in watts,
I = current in amperes,
R = resistance in ohms.

2.81. ***Question.*** **What is the formula for determining the power in a d-c circuit when the current and voltage are known?**

Answer.

$P = EI$, where P = power in watts,
E = e.m.f. in volts,
I = current in amperes.

2.82. ***Question.*** **What is the formula for determining the wavelength when the frequency, in kilocycles, is known?**

Answer.

$\lambda = \frac{V}{f \times 1{,}000}$, where λ = wavelength in meters,
V = velocity of radio wave in space, or 300,000,000 meters per second,
f = frequency in kilocycles.

The formula may also be written as follows where velocity, 300,000,000, is first divided by 1,000 to give 300,000 and with the given frequency in kilocycles inserted for f, thus,

$$\lambda = \frac{300{,}000}{f} \text{ meters}$$

2.83. ***Question.*** **What is the frequency corresponding to a wavelength of 375 meters?**

Answer. 800 kilocycles, or 800,000 cycles.

Computation: The wavelength formula to find frequency is $f = V \div \lambda$. Inserting known values, then $f = 300{,}000{,}000 \div 375 = 800{,}000$ cycles.

2.84. ***Question.*** **Define the term "apparent power."**

Answer. The "apparent power" in an a-c circuit is the power that would be indicated from multiplying volts by amperes, neglecting the power factor.

Discussion. In a purely resistive circuit, or one without reactance effects, the product of volts times amperes gives the true power. In a circuit with reactance effects there is a certain phase difference between the voltage acting and the current flowing; hence the *total* *current* is made up of the *effective current* which contributes to the power in the circuit and the *wattless current component* which is forced through the circuit one way or the other by the reactance voltages. The *apparent power* includes that part of the power returned to the source.

2.85. *Question.* State Ohm's law for a-c circuits.

Answer. The current in a circuit is directly proportional to the voltage applied and inversely proportional to the impedance of the circuit.

In mathematical form this relationship is written $I = E/Z$, or $E = IZ$, or $Z = E/I$.

The complete form for expressing this law is

$$I = \frac{E}{\sqrt{R^2 + (X_L - X_C)^2}}, \quad \text{or} \quad I = \frac{E}{\sqrt{R^2 + \left(2\pi fL - \dfrac{1}{2\pi fC}\right)^2}}$$

2.86. *Question.* Draw a simple schematic diagram showing a tuned-plate tuned-grid oscillator with series-fed plate. Indicate polarity of supply voltages.

Answer. See Figure 2.

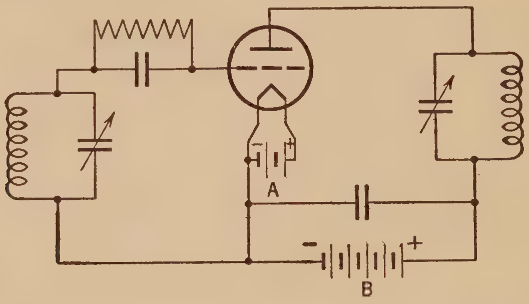


FIG. 2. Schematic diagram of a tuned-plate tuned-grid oscillator with series-fed plate.

2.87. *Question.* Draw a simple schematic diagram showing a Hartley triode oscillator with shunt-fed plate. Indicate power supply polarity.

Answer. See Figure 3.

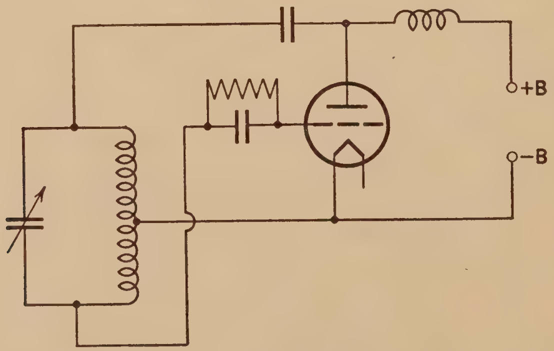


FIG. 3. Schematic diagram of Hartley oscillator with shunt-fed plate.

2.88. *Question.* Draw a simple schematic diagram showing a tuned-grid Armstrong type triode oscillator, with shunt-fed plate. Indicate power supply polarity.

Answer. See Figure 4.

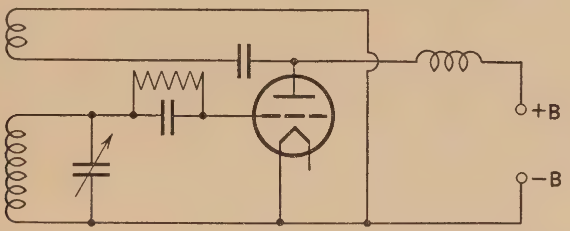


FIG. 4. Schematic diagram of a tuned-grid Armstrong oscillator with shunt-fed plate.

2.89. *Question.* Draw a simple schematic diagram showing a tuned-plate tuned-grid triode oscillator with shunt-fed plate. Indicate polarity of supply voltages.

Answer. See Figure 5.

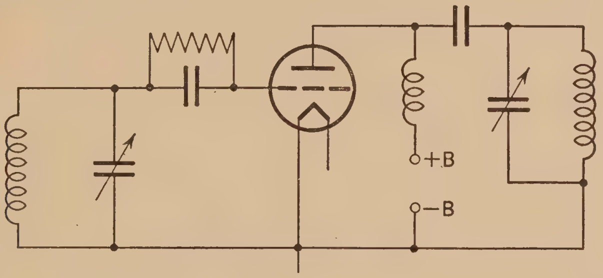


FIG. 5. Schematic diagram of a tuned-grid tuned-plate oscillator with shunt-fed plate.

2.90. *Question.* Draw a simple schematic diagram of a crystal-controlled vacuum-tube oscillator. Indicate power supply polarity.

Answer. See Figure 6.

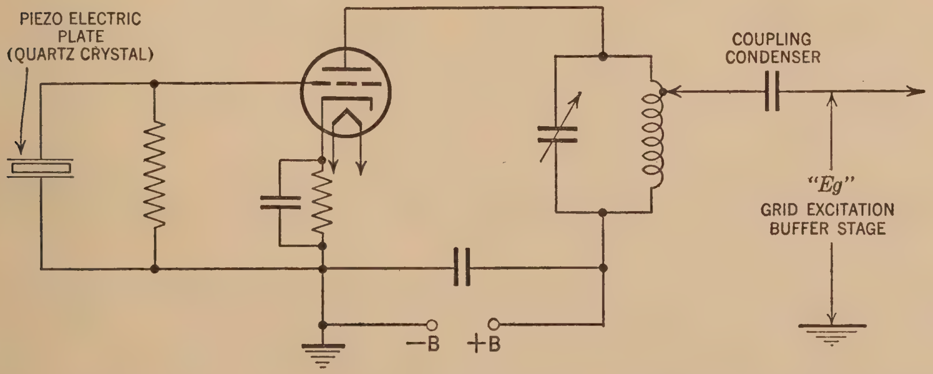

PIEZO ELECTRIC PLATE (QUARTZ CRYSTAL)
COUPLING CONDENSER
"Eg"
GRID EXCITATION BUFFER STAGE
−B
+B

FIG. 6. Schematic diagram of a crystal-controlled oscillator showing how the buffer amplifier grid is coupled to the plate tank to receive r-f excitation.

2.91. ***Question.*** **Draw a simple schematic diagram showing a Colpitts type triode oscillator, with shunt-fed plate. Indicate power supply polarity.**

Answer. See Figure 7.

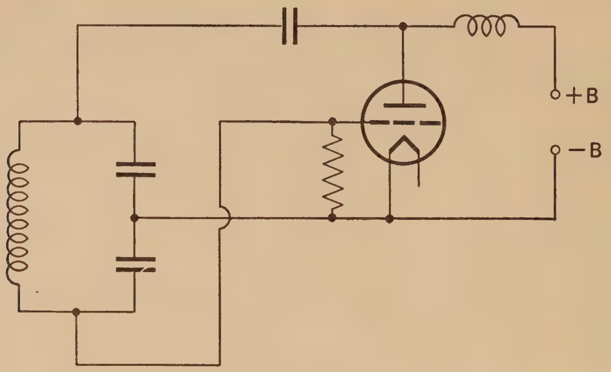


FIG. 7. Schematic diagram of Colpitts oscillator with shunt-fed plate.

2.92. ***Question.*** **Draw a simple schematic diagram showing a tuned-grid Armstrong type triode oscillator, with series-fed plate. Indicate power supply polarity.**

Answer. See Figure 8.

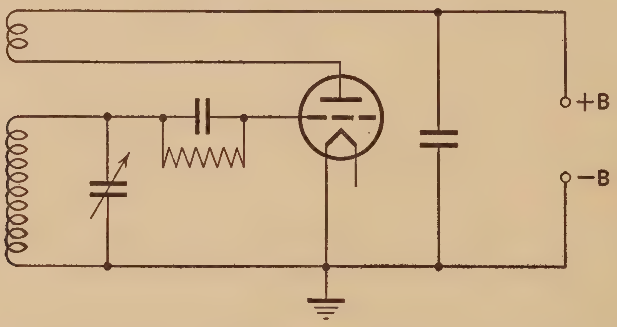


FIG. 8. Schematic diagram of a tuned-grid Armstrong oscillator with series-fed plate.

2.93. ***Question.*** **Draw a simple schematic diagram of an electron coupled oscillator, indicating power supply polarities where necessary.**

Answer. See Figure 9.

2.94. ***Question.*** **Draw a simple schematic diagram of a pentode type tube used as a crystal-controlled oscillator, indicating power supply polarities.**

Answer. See Figure 10.

2.95. ***Question.*** **Draw a simple schematic circuit showing a method of coupling a high impedance loudspeaker to an audio-frequency amplifier tube without flow of plate current through the speaker windings, and without the use of a transformer.**

Answer. See Figure 11.

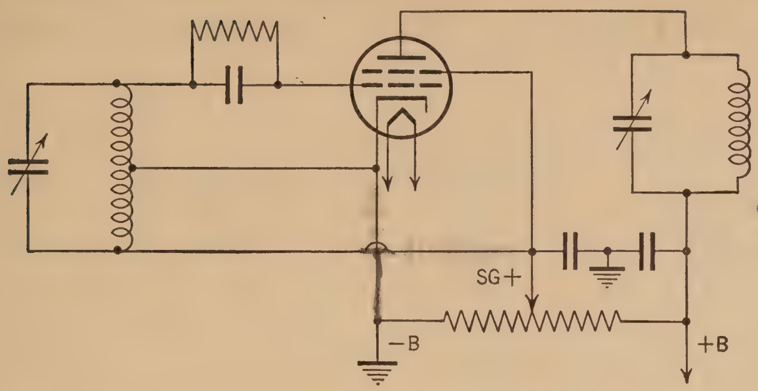


FIG. 9. Schematic diagram of an electron coupled oscillator.

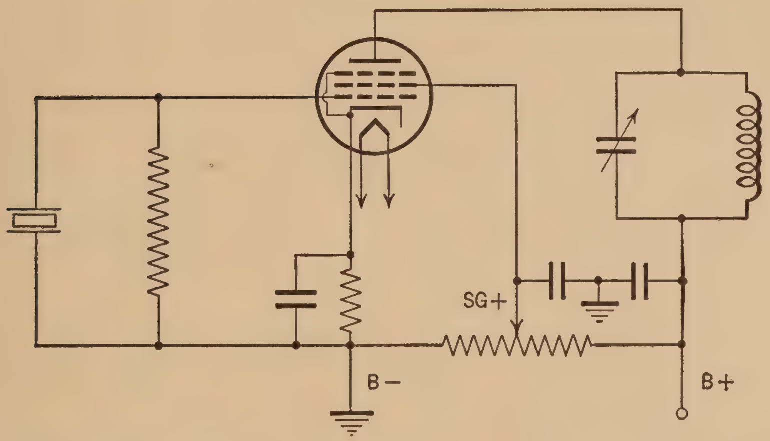


FIG. 10. Schematic diagram of a crystal-controlled oscillator using a pentode tube.

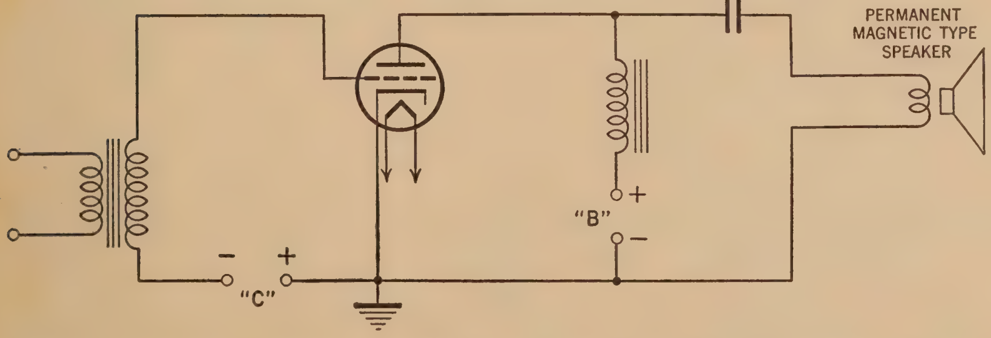


FIG. 11. A loudspeaker which is impedance coupled to prevent flow of direct current through speaker winding.

2.96. *Question.* Draw a simple schematic diagram of a triode vacuum tube audio-frequency amplifier inductively coupled to a loudspeaker.

Answer. See Figure 12.

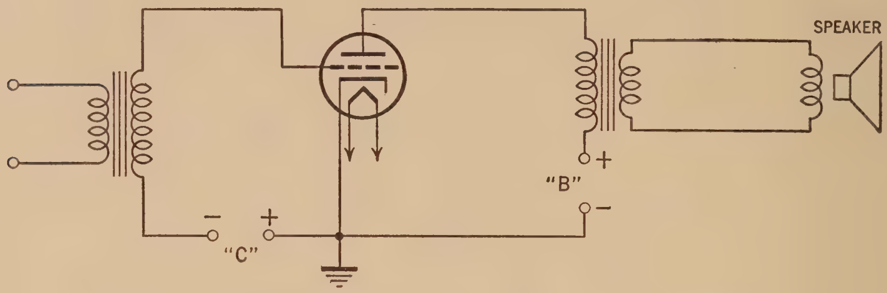


FIG. 12. A loudspeaker inductively coupled to an audio amplifier.

2.97. *Question.* Draw a simple schematic circuit showing a method of resistance coupling between two triode vacuum tubes in an audio-frequency amplifier.

Answer. See Figure 13.

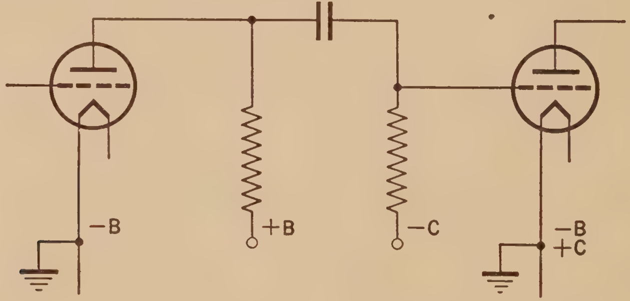


FIG. 13. Resistance coupling used between two audio stages.

2.98. *Question.* Draw a simple schematic diagram showing a method of transformer coupling between two triode vacuum tubes in an audio-frequency amplifier.

Answer. See Figure 14.

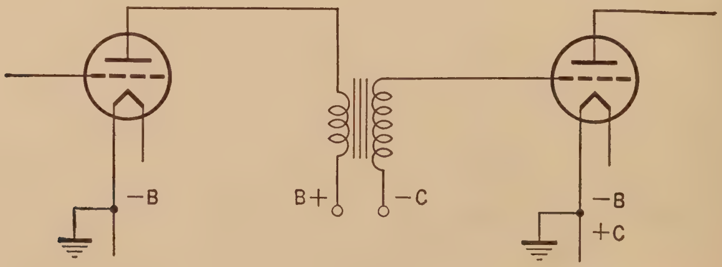


FIG. 14. Transformer coupling used between two audio stages.

2.99. *Question.* Draw a simple schematic diagram of a method of impedance coupling between two vacuum tubes in an audio-frequency amplifier.

Answer. See Figure 15.

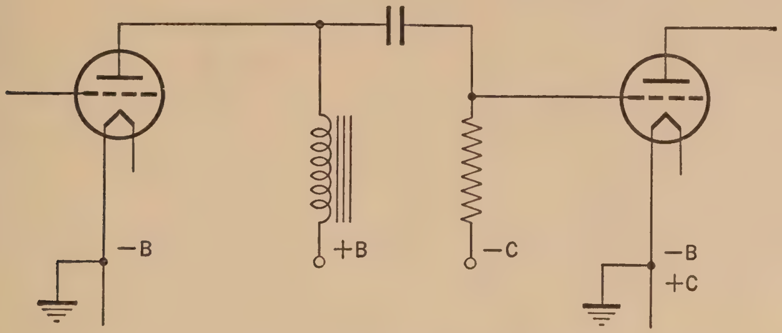


FIG. 15. Impedance coupling used between two audio stages.

2.100. *Question.* Draw a diagram of a method of coupling a single radio-frequency amplifier using a triode vacuum tube to a push-pull radio-frequency amplifier using triode vacuum tubes, showing proper neutralization of the push-pull amplifier.

Answer. See Figure 16.

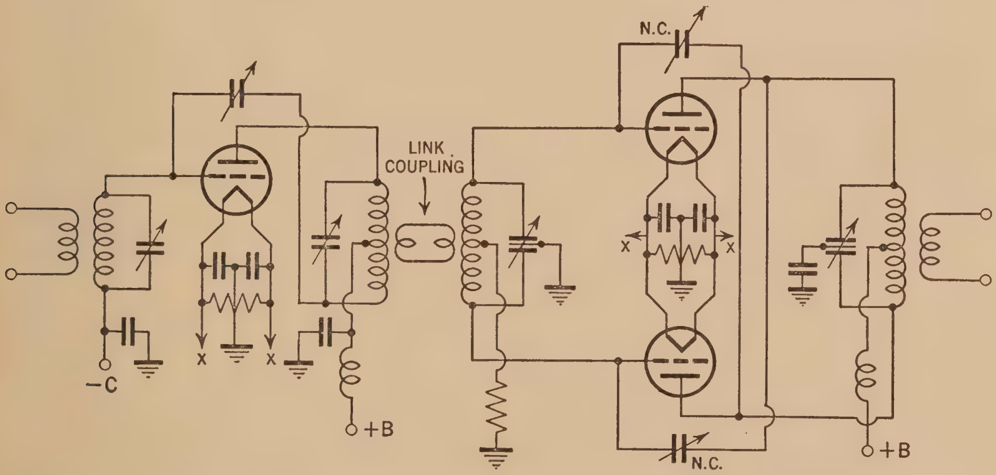


FIG. 16. A push-pull r-f amplifier coupled to a single r-f amplifier with both stages neutralized. The points marked x connect to the filament transformer winding not shown.

2.101. *Question.* Draw a simple schematic circuit diagram of a radio-frequency amplifier, employing a triode vacuum tube and making use of plate neutralization.

Answer. See Figure 17. The inventor of "plate" neutralization is Hazeltine.

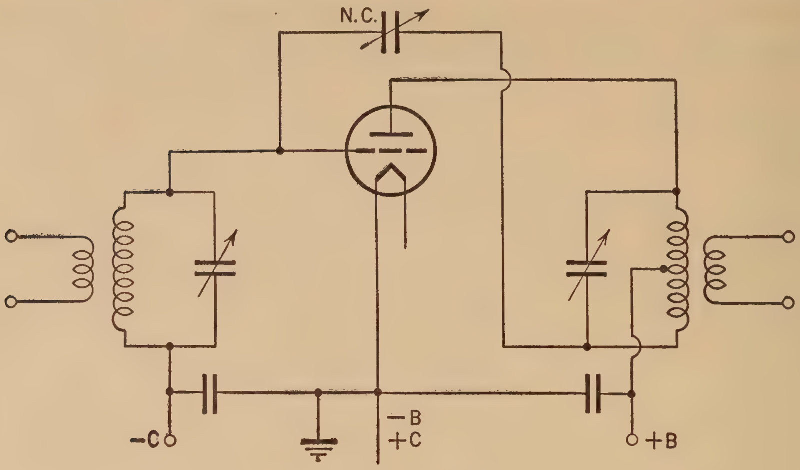


FIG. 17. An r-f amplifier using Hazeltine or plate neutralization.

2.102. *Question.* Draw a simple schematic circuit diagram of a radio-frequency amplifier, employing a triode vacuum tube and making use of grid neutralization.

Answer. See Figure 18. The inventor of "grid" neutralization is Rice.

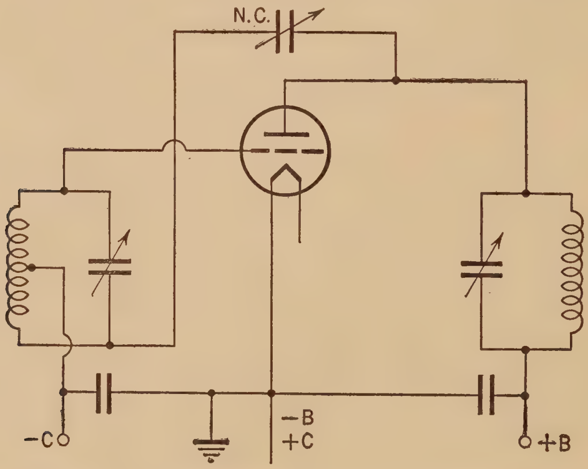


FIG. 18. Illustrating grid neutralization of an r-f amplifier, invented by Rice.

2.103. *Question.* Draw a simple schematic diagram showing a method of coupling the radio-frequency output of the final power amplifier stage of a transmitter to an antenna.

Answer. See Figure 19.

2.104. *Question.* Draw a simple schematic diagram showing a method of coupling between two tetrode vacuum tubes in a tuned radio-frequency amplifier.

Answer. See Figure 20.

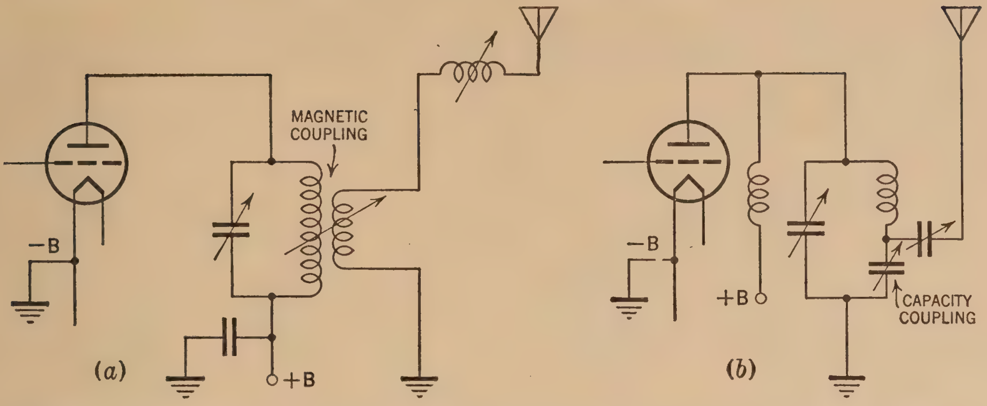


FIG. 19. Simple diagrams showing two methods by which a final r-f stage may be coupled to an antenna, through the use of either a transformer or a condenser.

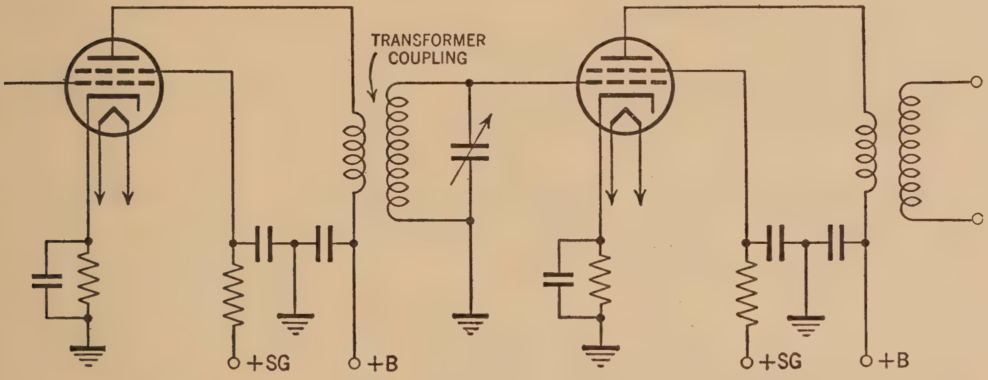


FIG. 20. Two r-f stages employing tetrode tubes are coupled by means of a transformer.

2.105. *Question.* Draw a simple schematic diagram showing a method of coupling between two triode vacuum tubes in a tuned radio-frequency amplifier, and a method of neutralizing to prevent oscillation.

Answer. See Figure 21.

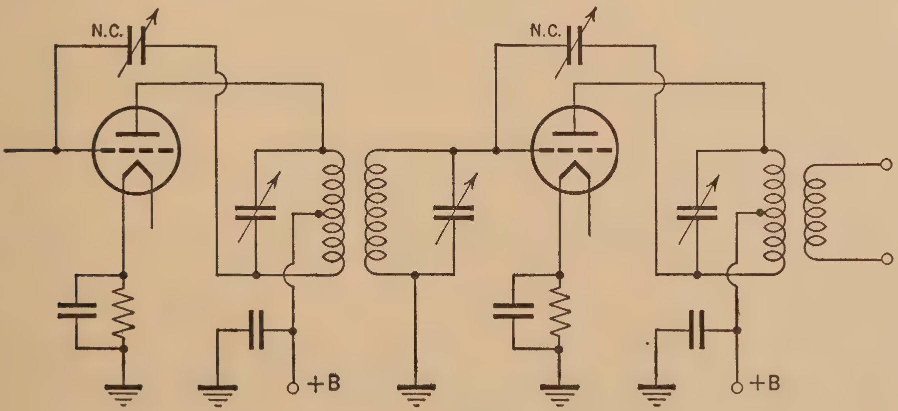


FIG. 21. Two neutralized r-f stages using triode tubes are shown coupled through a transformer.

2.106. *Question.* Draw a simple schematic diagram of a diode vacuum tube connected for diode detection, and showing a method of coupling to an audio amplifier.

Answer. See Figure 22.

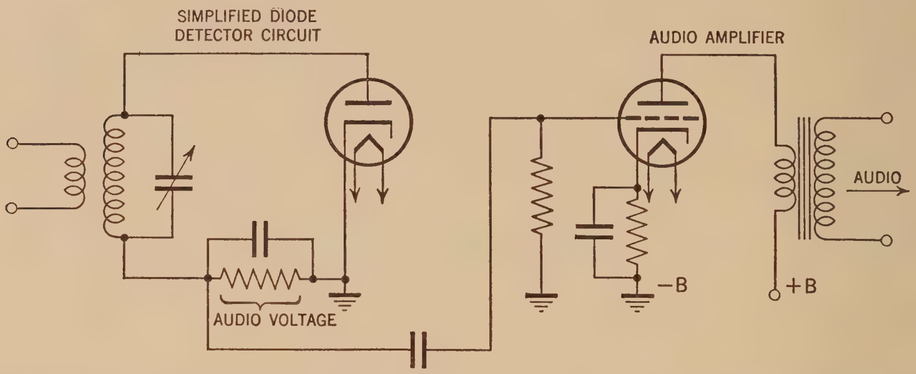


FIG. 22. Simple diagram of a diode tube operating in a detector stage and shown coupled to an audio amplifier.

2.107. *Question.* Draw a simple schematic diagram of a triode vacuum tube connected for plate or "power" detection.

Answer. See Figure 23.

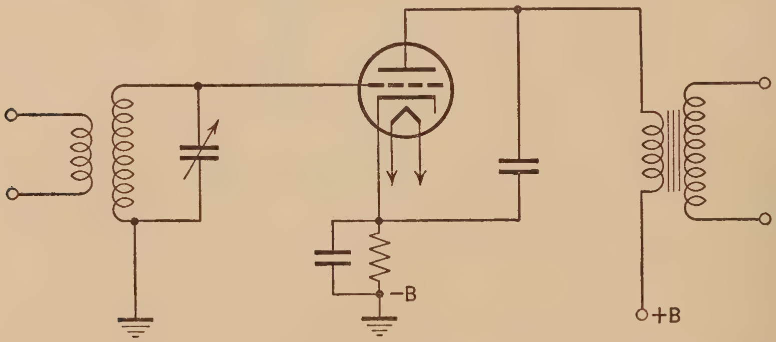


FIG. 23. A triode tube connected for plate or "power" detection and employing cathode bias.

2.108. *Question.* Draw a simple schematic diagram of a triode vacuum tube connected for grid-leak condenser detection.

Answer. See Figure 24.

2.109. *Question.* Draw a simple schematic diagram of a regenerative detector.

Answer. See Figure 25.

2.110. *Question.* Draw a simple schematic circuit of a radio-frequency doubler stage, indicating any pertinent points which will distinguish this circuit as that of a frequency doubler.

Answer. See Figure 26.

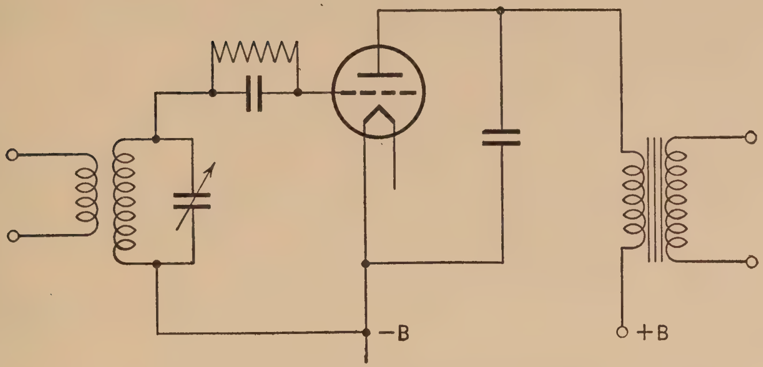


FIG. 24. A triode tube connected for grid-leak condenser detection.

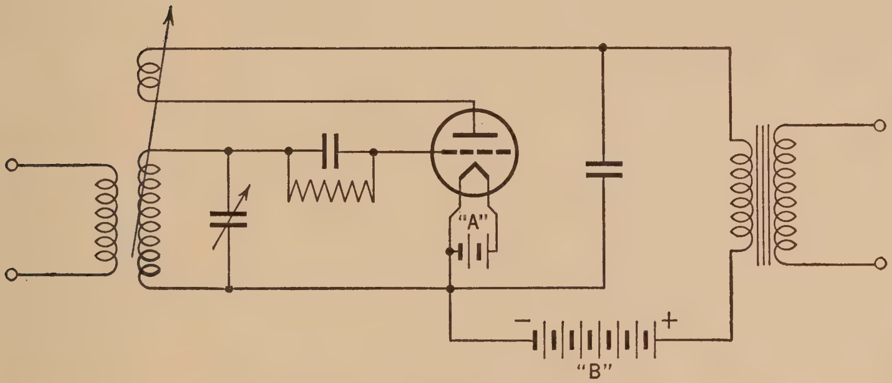


FIG. 25. A regenerative detector.

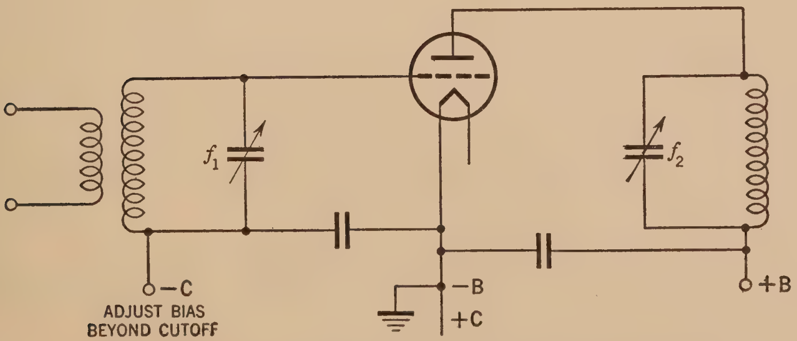


FIG. 26. A frequency doubler operated with bias adjusted beyond cutoff similar to class C operation and with the plate tank tuned to twice the fundamental frequency.

2.111. *Question.* Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be two-thirds the resistance of one unit.

Answer. See Figure 27.

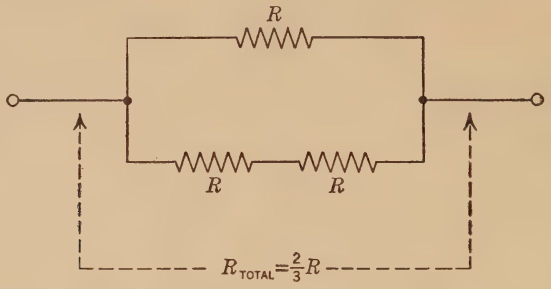


FIG. 27. In this simple arrangement all resistors are of equal value.

2.112. *Question.* Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be one and one-half times the resistance of one unit.

Answer. See Figure 28.

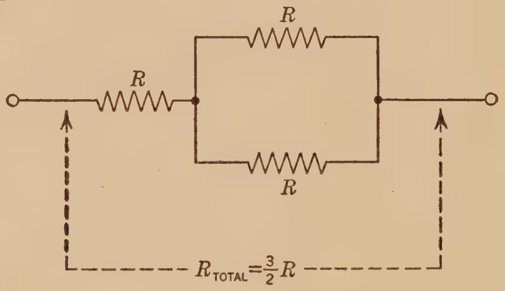


FIG. 28. All resistors are of equal value.

2.113. *Question.* Draw a simple schematic diagram to indicate how a 60-cell bank of lead-acid storage batteries may be connected to permit charging in parallel from a 110-volt d-c source and discharging in series, including necessary switches.

Answer. See Figure 29.

2.114. *Question.* Draw a diagram of a simple shunt rejector or wave-trap circuit, in series with a receiving antenna, designed to suppress an undesired signal.

Answer. See Figure 30.

2.115. *Question.* Draw a diagram of a simple series wave-trap circuit, connected in shunt with the input terminals of a radio receiver and designed to bypass an undesired signal.

Answer. See Figure 31.

2.116. *Question.* Draw a simple schematic diagram of an underload circuit breaker as used with battery-charging circuits.

Answer. See Figure 32.

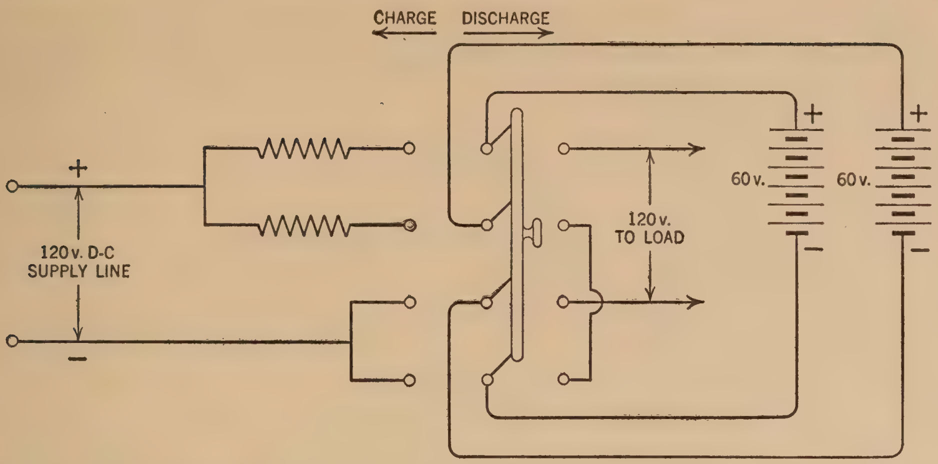


FIG. 29. Two 60-cell battery banks shown connected to a four-pole double-throw switch for charging in parallel and discharging in series. Each bank consists of 30 cells indicated as 60 volts.

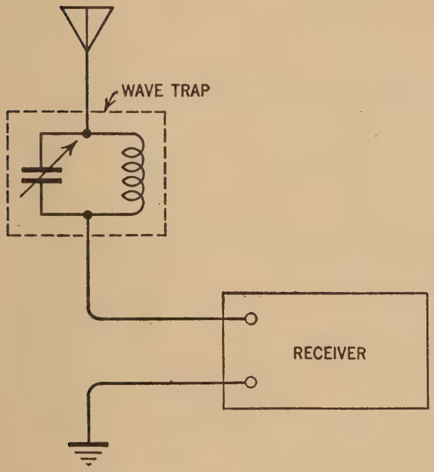


FIG. 30. A shunt rejector type wave-trap in series with a receiving antenna.

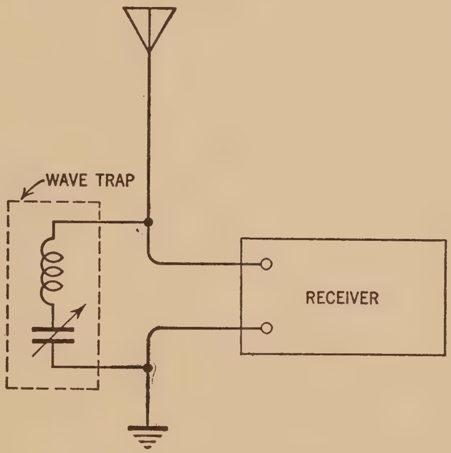


FIG. 31. A series type wave-trap connected across receiver input terminals.

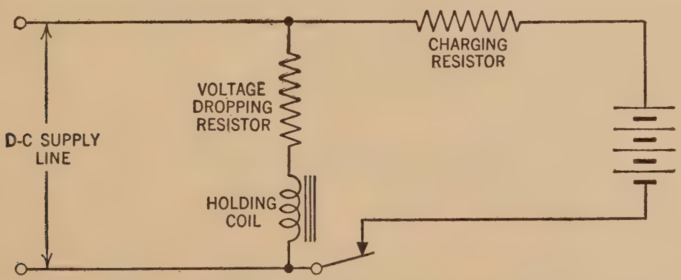


FIG. 32. One type of underload circuit breaker as used with battery-charging circuits.

2.117. *Question.* Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be one-third of one unit.

Answer. See Figure 33.

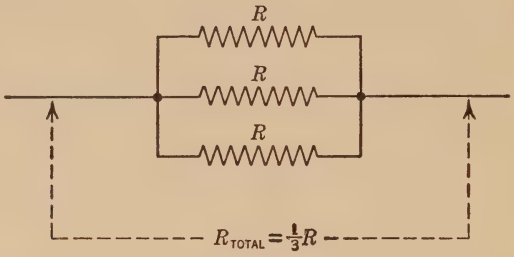


FIG. 33. Resistors of equal value connected in parallel.

2.118. *Question.* Draw a simple schematic diagram of a shunt-wound, self-excited, d-c motor, with provision for starting and regulating speed, including indication of the d-c source.

Answer. See Figure 34.

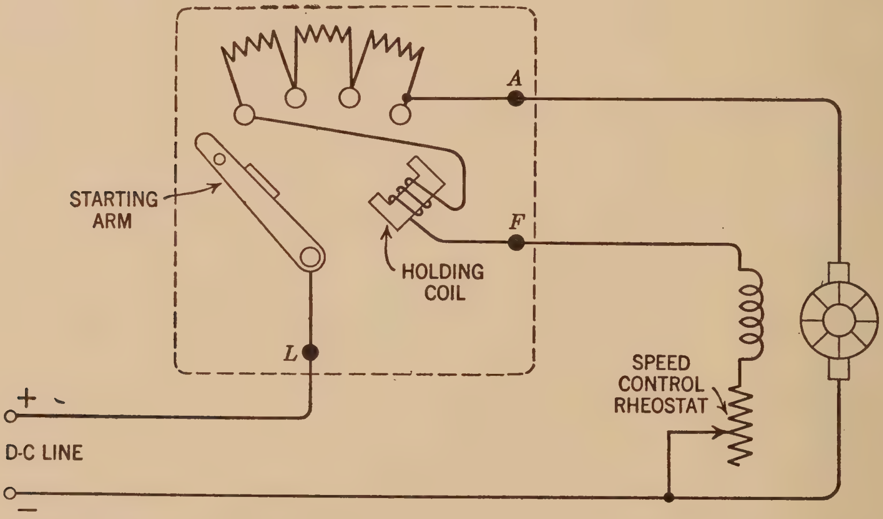


FIG. 34. Three-terminal hand starter connected to d-c shunt motor with speed control.

2.119. *Question.* Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be three times the resistance of one unit.

Answer. See Figure 35.

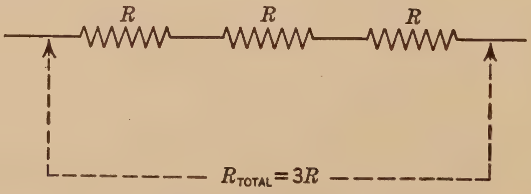


FIG. 35. Series arrangement of resistors.

2.120. *Question.* **Draw a diagram of a single-button carbon microphone circuit, including the microphone and source of power.**

Answer. See Figure 36.

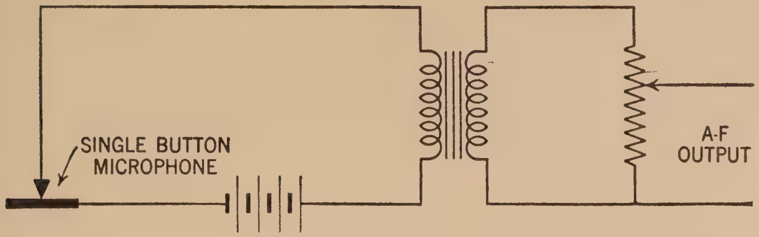


FIG. 36. Single button microphone circuit.

2.121. *Question.* **What is meant by a "soft" vacuum tube?**

Answer. A tube having a degree of vacuum lower than for a normal condition, due to the presence of a slight amount of gas, is called a "soft" tube. During the exhaustion process special precautions are taken to remove every possible trace of gas from the elements and the space within the envelope. A tube with a very high degree of vacuum is called a "hard" tube.

2.122. *Question.* **What is meant by a "thyratron"?**

Answer. A "thyratron" is a type of hot-cathode mercury-vapor tube with a plate, a filament for the cathode, and one or more control grids having characteristics which make the tube suitable for special uses in commercial applications as a rectifier and in power control devices.

Discussion. The characteristic action of this tube is different from ordinary diode rectifiers which do not have a grid. During operation of the *thyratron* the grid potential is made to block the plate current, but once the grid potential changes and allows the plate current to flow, the plate current then is dependent essentially on the plate voltage. The action of the grid is such that it cuts off plate current at one time and then opens wide to allow full plate current which varies and follows the plate voltage changes from a power source. These functions permit the thyratron to be used also in other commercial applications such as the inverter, a device used for changing direct current to alternating current. This tube can handle relatively large currents at high voltages. Like other mercury-vapor tubes it has a low internal voltage drop which is practically constant, thus giving it good voltage regulation characteristics.

2.123. *Question.* **Describe the physical structures of the triode, tetrode, and pentode on a comparative basis.**

Answer. **Triode.** The triode consists of three electrodes, namely, plate, control grid, and cathode with the grid wire located between plate and cathode while the plate surrounds the whole. The cathode may be of the filamentary type or the indirectly heated type.

Tetrode. The tetrode has four electrodes, three of which are similar to the triode and the fourth is an additional grid, called screen grid, located between plate and control grid.

Pentode. The pentode consists of five electrodes, four of which are similar to the tetrode but with a third grid, called suppressor grid, located between the plate and screen grid.

2.124. *Question.* Describe the electrical characteristics of the pentode, tetrode, and triode on a comparative basis.

Answer. The suppressor grid of the **pentode** is the only physical difference between the tetrode and the pentode. Electrically, both possess the shielding action of the screen grid which results in a low direct interelectrode capacitance between control grid and plate.

The **triode,** on the other hand, has a large interelectrode capacitance due to the absence of the screen grid, and hence electrostatic coupling between the plate and control grid circuits is effected within the tube.

In the **tetrode,** secondary emission from the plate makes the tube unstable for plate voltages below that of the screen. This effect has been eliminated in the pentode by the suppressor grid and as a result a much greater extent of the characteristic can be utilized. In general, this makes for lower distortion and in power tubes greater output power as well. See curves in Figure 58(*a*).

2.125. *Question.* What are the visible indications of a "soft" tube?

Answer. The space inside the glass envelope gives a visible *blue glow* from the increased ionization due to the presence of gas. In a soft tube the degree of vacuum is lower than normal.

2.126. *Question.* Describe the physical structure of a triode vacuum tube.

Answer. A **triode** tube consists of three elements, namely, plate, grid, and cathode. The cathode in the directly heated type is the filament itself, whereas in the indirectly heated type the cathode consists of an oxide-coated surface which provides the electron emission. The grid, spaced next, consists of a fine wire shaped like a spiral with only one end making connection to the external circuit. Mounted outside the grid, and hence surrounding the filament and grid, is the plate which consists of a flat solid surface formed somewhat like a cylinder, which also requires but one connection to the external circuit. These elements are contained within a highly evacuated bulb, called envelope, made of glass or metal, according to the type of tube, and the connections to the electrodes are brought out to the side or top of the envelope, or to pins or prongs in the tube base.

2.127. Question. Describe the physical structure of a tetrode vacuum tube.

Answer. A **tetrode** tube consists of four elements, namely, a cathode which may consist of either a filament wire or oxide-coated surface used for the emitter; next comes a grid, control grid, which is a fine wire wound in spiral form; then another grid, suppressor grid, which is also a thin wire spiral-shaped to provide spaces between the grid wire meshes; and last, surrounding the whole, is the plate, a solid surface, flat and shaped somewhat like a cylinder. The tube is highly evacuated, and suitable connections are provided to the electrodes.

2.128. *Question.* Does a pentode vacuum tube usually require neutralization when used as a radio-frequency amplifier?

Answer. A pentode tube generally does not need neutralization. The screen grid effectively reduces the interelectrode capacitance between plate and control grid so that feedback from plate to grid is not sufficiently great to cause self-oscillation. Where ultra-high frequencies are involved conditions may require some form of neutralization.

2.129. ***Question.*** **What is the meaning of "plate impedance"?**

Answer. The term "plate impedance" refers to the internal behavior of a tube between its plate and cathode when a pulsating current flows because certain characteristic effects result similar to resistance and reactance, due respectively to the d-c and a-c components of the current. Both of these effects, namely, resistance and capacitive reactance, represent the internal "plate impedance." If the capacitive reactance effects are not to be taken into account for any particular reason then the effective internal plate-to-cathode resistance is considered to be the plate impedance of the tube.

2.130. ***Question.*** **What is the meaning of "mutual conductance"? What is the meaning of "transconductance"?**

Answer. "Mutual conductance" is a term used to express the ratio of amplification factor to plate resistance, and is the quotient of one by the other. This relation is expressed in the following formula where G_m is mutual conductance, μ is amplification factor, and R_p is plate resistance, or

$$G_m = \frac{\mu}{R_p}$$

In other words, "mutual conductance" indicates the control-grid to plate transconductance, or simply transconductance, and in one term expresses the relation of amplification factor and plate resistance.

"Transconductance" may be defined as the ratio of a small change in plate current, expressed in amperes, to the small change in control grid voltage producing it, providing that all other voltages remain unchanged.

2.131. ***Question.*** **What is the meaning of "secondary emission"?**

Answer. "Secondary emission" is electron emission due directly to the impact of electrons or ions.

Discussion. When electrons reach the plate from the cathode of a tube the impact knocks electrons out of the plate; the electrons in the main stream from cathode to plate are called the *primary* emission electrons and the electrons released at the plate the *secondary* emission electrons. Thus, it requires a primary source to get secondary emission effects.

2.132. ***Question.*** **What is the meaning of "amplification factor"?**

Answer. "Amplification factor" may be defined as the ratio of the change in plate voltage to a change in control-grid voltage in the opposite direction that would give the same plate current, providing all other voltages are kept constant.

Discussion. The meaning of "amplification factor" given above is made clear by the following example: Suppose the positive plate voltage is increased by 1 volt and the plate current increases by a certain amount; then if the grid voltage were made more negative, say by 0.1 volt, the plate current would now reduce to its first value. In this case the amplification factor would be 1 ÷ 0.1, or 10. There are many possible combinations of grid and plate voltages that will give the same plate current, and it can be seen that a relatively small change in grid voltage would have the same effect on the variation in plate current as a large change in plate voltage. This term suggests comparison of the amplitude of the signal in the grid and plate circuits, and thus is an indication of the amount of amplification that may be expected.

2.133. *Question.* What is the meaning of "electron emission"?

Answer. "Electron emission" is the liberation of electrons from an electrode into the surrounding space. Quantitatively, it is the rate at which electrons are emitted from an electrode. (A.I.E.E. definition.)

Discussion. When the agitation which brings on emission is due to raising the temperature of an electrode, the expression *thermionic emission* may be applied. Electrons which ordinarily remain within the body of a conducting material will be agitated by the application of heat. In moving about with increased velocity many electrons reach the surface of the material and overcome the surface forces which tend to keep them within. When electrons actually separate from the material and escape into the surrounding space *emission* is said to take place.

2.134. *Question.* Describe the characteristics of a vacuum tube operating as a class C amplifier.

Answer. High plate circuit efficiency and high power output are two important characteristics of a class C amplifier. Although the power output is high the power amplification is low. A large amount of harmonic distortion is generated in the output. The grid is allowed to swing positive.

Discussion. The high plate circuit efficiency possible from this class of amplifier in some cases is around 75 per cent, the high value being obtained generally by swinging the grid sufficiently positive to cause plate current saturation. This accounts for another main characteristic of class C operation, large distortion, since driving the grid positive and employing a small angle of plate current flow with high peaks causes the generation of a considerable amount of third harmonic energy to be introduced in the tube's output.

The grid bias used is considerably greater than cutoff value, from one and a half to twice cutoff and sometimes higher, and therefore a signal of large amplitude is required for grid excitation to produce the exceedingly large plate current amplitudes which flow for only a small part of each positive half cycle of excitation.

A vacuum tube operating class C cannot be used in an audio-frequency stage, only with radio-frequency, or tuned circuits.

The theoretical maximum plate circuit efficiency is 100 per cent. (Note that plate circuit efficiency means the ratio of a-c power output to average d-c power input.)

2.135. *Question.* During what approximate portion of the excitation voltage cycle does plate current flow when a tube is used as a class C amplifier?

Answer. In a class C amplifier plate current flows for considerably less than 180 degrees of the least negative portion of the grid exciting voltage.

2.136. *Question.* Describe the characteristics of a vacuum tube operating as a class A amplifier.

Answer. The main characteristics of class A operation are as follows:

(*a*) Plate circuit efficiency is very low. The plate efficiency, theoretically, cannot be greater than 50 per cent, and in actual practice it is about 20 to 30 per cent.

(*b*) Power output is medium.

(*c*) Power amplification is high; a high ratio of voltage amplification.

(*d*) Distortion is negligible. There is practically no serious distortion of the wave form with proper adjustment and excitation since the tube is worked within the linear part of its grid-voltage plate-current characteristic curve.

(*e*) Grid drive requirements are limited to prevent distortion. The signal voltage should never be so large as to drive the grid positive and cause grid current to flow, or make the grid so negative as to cut off the plate current.

(*f*) A main characteristic of class A operation is that the grid bias is adjusted to a value much less than cutoff, thus allowing plate current to flow during the complete cycle of grid excitation.

2.137. *Question.* Describe the characteristics of a vacuum tube operating as a class B amplifier.

Answer. The main characteristics of a class B amplifier are listed as follows:

(*a*) Medium power output; the power output is proportional to the square of the excitation voltage applied to the grid.

(*b*) The grid bias is adjusted at or near cutoff value so that the plate current is nearly zero, or relatively low with no signal excitation; plate current flows for substantially 180 degrees of each excitation cycle.

(*c*) The average d-c component of the plate current varies considerably from zero signal to maximum signal conditions during operation, which makes it necessary to use a plate power supply having good voltage regulation.

(*d*) A larger grid exciting voltage is required for class B than for class A. In the operation of a class B amplifier tube, where a large grid exciting voltage is available, the grid is allowed to be driven positive within certain limits and with practically negligible distortion of the wave shape.

(*e*) Medium plate circuit efficiency is a characteristic of class B. The theoretical maximum efficiency is 78.3 per cent, but practical efficiencies are in the order of about 30 to 50 per cent.

(*f*) The ratio of power amplification is only moderate and is lower than for class A. However, this low power amplification is offset by making a class B stage give a much higher output power and with virtually undistorted output. Good reproduction of the wave shape of the grid exciting voltage may be expected from class B.

(*g*) A class B amplifier can be used for both radio-frequency and audio-frequency amplification; however, for audio circuits two tubes must be used in push-pull in a balanced circuit to produce each half cycle of the grid excitation wave.

2.138. *Question.* During what portion of the excitation voltage cycle does plate current flow when a tube is used as a class B amplifier?

Answer. Plate current flows during approximately 180 degrees, or one-half of each cycle of the exciting voltage.

2.139. *Question.* Does a properly operated class A audio amplifier produce serious modification of the input wave form?

Answer. No.

2.140. *Question.* What is the meaning of the term "maximum plate dissipation"?

Answer. "Maximum plate dissipation" is the maximum power which a plate dissipates in the form of heat due to the electron impact at the plate. Plate dissipation is the difference between the plate input (power supplied to the plate) and power output (power delivered by the tube to the load, that is, the alternating component in the load that represents the signal). The plate dissipation should never exceed the maximum values or ratings recommended in tube charts for typical operating conditions.

2.141. *Question.* What is meant by a "blocked grid"?

Answer. A "blocked grid" means a grid on which the negative potential is sufficiently great to prevent plate current flow.

2.142. *Question.* What is meant by the "load" on a vacuum tube?

Answer. The "load" on a vacuum tube is the equivalent impedance presented to its output. This usually is either a physical or equivalent resistance but it may have a reactive component as well, which would be the case for an inductive or capacitive load.

2.143. *Question.* What circuit and vacuum tube factors influence the voltage gain of a triode audio-frequency amplifier stage?

Answer. (*a*) For circuit conditions: The gain is influenced by coupling where transformer coupling would give a gain depending on the turns ratio, but no gain with resistance coupling.

(*b*) For the tube used and its operation: The gain is influenced by amplification factor, grid exciting voltage, and plate voltage.

2.144. *Question.* What is the purpose of a bias voltage on the grid of an audio-frequency amplifier stage?

Answer. The bias voltage is used to adjust the working point on the plate-current grid-voltage characteristic for a desired operation of the amplifier tube. In the case of class A audio amplifiers the grid is biased to prevent the flow of grid current; in class B a very small grid current is permissible.

2.145. *Question.* What is the primary purpose of a screen grid in a vacuum tube?

Answer. The electrostatic capacity between control grid and plate is reduced to a negligible value by the screen grid, which acts to shield the plate. This results in insufficient feedback to cause self-oscillation; hence neutralization is unnecessary in most amplifiers using a screen grid tube.

2.146. Question. What is the primary purpose of a suppressor grid in a multielement vacuum tube?

Answer. The suppressor grid effectively prevents secondary emission effects. That is, secondary electrons leaving the plate do not find a positively charged electrode in the vicinity which would attract them, but instead the adjacent suppressor grid, being held at a negative or ground potential, repels them, thus causing them to return to the plate.

2.147. *Question.* What is the meaning of the term "plate saturation"?

Answer. "Plate saturation" occurs when the plate current equals the filament emission. Under such conditions the plate is taking all of the electrons emitted by the cathode.

2.148. *Question.* What is the most desirable factor in the choice of a vacuum tube to be used as a voltage amplifier?

Answer. A tube with a high mu (μ) would be best suited for use as a voltage amplifier.

2.149. *Question.* What is the principal advantage of a tetrode over a triode as a radio-frequency amplifier?

Answer. The principal advantage is the low plate-to-grid capacitance of the tetrode.

Discussion. The low internal plate-to-grid capacitance reduces feedback effects and ordinarily obviates the need of a neutralizing circuit. The tetrode has a high theoretical voltage amplification factor, μ, but actual load conditions allow realization of only a fraction of this apparent advantage.

2.150. *Question.* What is the principal advantage of the tetrode compared to the triode, when used in a radio receiver?

Answer. Neutralization circuits are not required for the r-f amplifiers.

2.151. *Question.* What is the principal advantage in the use of a diode detector instead of a grid-leak type triode detector?

Answer. High fidelity is the principal advantage. A diode detector only rectifies a signal and provides no amplification; hence it gives a more faithful reproduction of the signal wave form than a detector employing a grid.

2.152. *Question.* Draw a grid-voltage plate-current characteristic curve of a vacuum tube and indicate the operating points for class A, class B, and class C amplifier operation.

Answer. See Figure 37.

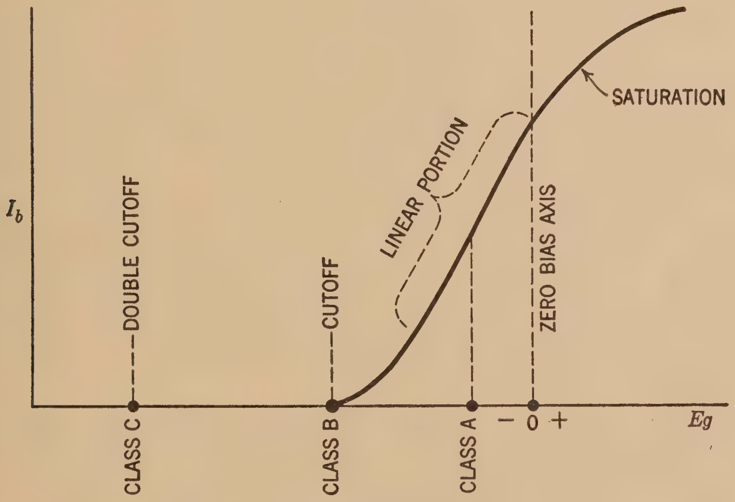


FIG. 37. Classes of operation of amplifiers are indicated.

2.153. *Question.* What operating conditions determine that a tube is being used as a "power detector"?

Answer. A power detector, where rectification takes place in the plate circuit, is operated under the following conditions:

(*a*) Grid is biased at slightly less than plate current cutoff value, called projected cutoff.

(*b*) Excitation voltage should not be permitted to swing the grid positive at any time.

(*c*) Grid circuit resistance is low.

(*d*) Plate voltage is determined by the type of tube employed; any power amplifier tube is suited for this purpose.

2.154. *Question.* **Why is it desirable to use an a-c filament supply for vacuum tubes?**

Answer. With a-c voltage on the filament there is a greater life expectancy from the filament, especially for high-power vacuum tubes. Alternating current voltage permits the use of transformers which provide a practical and efficient means for changing a higher line supply voltage to the required filament voltage and, in addition, the transformer electrically isolates the power line from the tube circuit. It is not always practicable to use d-c power line voltages for filament supply because resistors used to drop line voltage cause a large dissipation and, furthermore, the radio circuit cannot be then isolated from the power line. Another point is that alternating current for filament heating makes the use of batteries and charging circuits unnecessary, which simplifies the care and maintenance of the equipment.

2.155. *Question.* **Why is it advisable periodically to reverse the polarity of the filament potential of high power vacuum tubes when a d-c filament supply is used?**

Answer. When d-c voltage is used the potential gradient along the filament is constant with respect to the plate, so that one part of the filament becomes the principal source of electrons going to the plate, a condition which tends to shorten the useful life of the filament. However, with a-c the potentials are changing and no one particular section of the filament is constantly drawn on.

2.156. *Question.* **Why is it important to maintain transmitting tube filaments at recommended values?**

Answer. The greatest life expectancy will be realized by maintaining proper filament temperature. Overheating the filament by using excessive voltage or, on the other hand, operating at a temperature lower than normal may cause rapid disintegration of the filament material. Subnormal filament voltage lowers the electron emission and in turn affects the plate current, which may lead to improper operation of circuits.

2.157. *Question.* **How may certain vacuum tube filaments be reactivated?**

Answer. In general the **flashing** method is used for reactivation; yet there is a great variance of opinion regarding the amount of excess voltage and length of time of flashing to be employed. One method of treatment is explained in the following procedure: Remove all voltages from the tube except the filament voltage and adjust this voltage to three times the normal value. Flash for about 20 to 30 seconds and then follow by operating the filament at a reduced heat for about 30 to 60 minutes with the voltage held at 25 to 40 per cent above normal. This severe treatment may burn out some filaments and, therefore, it is not always successful. Only the thoriated tungsten filament may respond to reactivation because the wire is an alloy with the electron-emitting material distributed throughout and not merely coated on the surface of the wire. The increased electron agitation from flashing drives electrons toward the surface, forming a surface layer which make these electrons available for emission.

2.158. *Question.* **When an a-c filament supply is used, why is a filament center-tap usually provided for the vacuum tube plate and grid return circuits?**

Answer. The center-tap connection is used primarily to prevent an objectionable hum frequency (the frequency of the filament heating current) from appearing in the output along with the signal frequency.

Discussion. A center-tap connection is always at the same potential with respect to either side or leg of the filament circuit; hence the grid and plate potentials are practically unaffected by the a-c potentials across the filament. If the grid and plate returns were made to one side or the other of the filament and not to center-tap, the grid and plate would receive a changing potential according to the a-c frequency which would act similar to a modulating voltage and cause a large hum frequency in the output.

2.159. *Question.* **What types of vacuum tube filaments may be reactivated?**

Answer. Filament materials which may be reactivated are alloys or compounds; thoriated tungsten is an emitter of this type. Note that oxide-coated filaments cannot be reactivated.

2.160. *Question.* **Explain the operation of a "grid leak" type of detector.**

Answer. A high resistance grid leak is shunted by a condenser of small capacitance forming an *R-C* combination which is connected to the grid of the detector. An incoming signal acting across the condenser charges the grid end of the condenser to peak values on the positive half cycles, which causes the grid to accumulate electrons in impulses, known as rectified grid current. This action makes the grid end of the condenser negative at such moments, and it discharges through the high resistance leak. The discharge, however, is at a comparatively slow rate, or with an accumulative effect, so that the grid end is kept working at a varying negative potential which automatically adjusts itself according to the wave shape of the modulation envelope, or audio component. Hence the slow rate of flow of electrons returning to the cathode through the leak results in a voltage drop across the condenser and leak combination that represents the audio component. Since the audio frequencies appear as a separate voltage component on the grid they are amplified in the usual way in passing through the tube. In this type of detector the negative potential on the grid is provided by the signal itself, and it is being constantly varied according to the signal's characteristics of amplitude and frequency changes.

Discussion. By proper choice of condenser capacitance (250 micromicrofarads, a typical value) and leak resistance (in the order of 1 megohm), and with proper signal amplitude, the grid can be kept working at a negative potential which varies closely with the modulation envelope. However, if these conditions are not complied with and the condenser is not able to discharge through the leak at a rate which will allow its voltage to follow the modulation voltage wave then the grid becomes increasingly negative until, perhaps on a strong signal, the plate current is driven down to zero. Serious audio distortion will result if the plate current is cut off at any time. The grid-leak type of detector has very high sensitivity because weak signals acting on the grid cause comparatively large plate current changes below normal value; the average change represents the audio component. In this action the normal working point is at the lower bend in the grid-voltage plate-current characteristic curve.

2.161. *Question.* List and explain the characteristics of a "square law" type of vacuum tube detector.

Answer. The term "square law" applies to a detector employing a grid-leak and condenser. A list of characteristics and explanations follows:

(*a*) The plate current varies as the square of the grid excitation voltage.

(*b*) Rectification of the signal occurs in the grid circuit. That is, the audio component of the signal appears as a voltage on the grid because this is the voltage developed across the leak and condenser combination.

(*c*) The signal itself provides the negative working potential for the grid. No typical grid biasing methods are used in this principle of operation.

(*d*) The grid is easily overloaded by strong signals. With signals of large amplitude the distortion is great, since the grid potential becomes exceedingly negative owing to the slow leak-off through the high resistance. The grid then either blocks the plate current entirely over certain periods or causes a highly distorted average change in the region of cutoff.

(*e*) High sensitivity is possible with this type where large average changes in plate current are obtained from comparatively weak signals.

(*f*) A large amount of second harmonic distortion appears in the output. The generation of considerable harmonic energy is a normal condition in this kind of operation where the plate current axis, without signal, is moved to a new axis, with signal, according to the average change in plate current.

2.162. *Question.* Explain the operation of a diode type of detector.

Answer. In a diode detector the principle of rectification is used by means of two electrodes, plate and cathode, but for this purpose the plate current is sent through a resistor, shunted by a condenser, connected in series to the cathode, with plate excitation supplied by signal current in a tuned r-f circuit connected between plate and cathode. The operation is as follows: Plate current flows only on the positive half cycles of the signal wave so that the condenser charges up to peak values during plate current pulses and discharges through the resistor during the negative half cycles when no plate current is drawn. This action causes the condenser's voltage to vary according to the audio component of the signal.

2.163. *Question.* Explain the operation of a "power" or "plate rectification" type of vacuum tube detector.

Answer. The grid, in a *power detector*, is operated at a high bias, almost at cutoff, so that practically only the positive half cycles of the signal excitation cause plate current flow. Hence the average of all the changes in plate current is above normal value. This average represents the audio component which appears as an alternating voltage across the load in the plate circuit. This type of detector requires a large excitation, but it is not easily overloaded by strong signals; medium distortion and medium sensitivity are other characteristics. An advantage of this type is that if not overloaded, the selectivity of the input tuned circuit is not lowered and the Q is not affected because no power is taken by the detector from the tuned circuit, since no grid current is drawn in normal operation.

2.164. *Question.* Is a "grid-leak" type of detector more or less sensitive than a "power" detector (plate rectification)? Why?

Answer. The grid-leak detector is the most sensitive, as indicated by the fact that in this type the plate current (a-c component in the output) varies as the square of the excitation voltage on the grid. In a power detector the average plate current rises only in approximate proportion to the grid exciting voltage.

2.165. ***Question.*** **Describe what is meant by a "class A amplifier."**

Answer. An amplifier which is adjusted to work within the linear portion of the plate-current grid-voltage characteristic curve is a class A amplifier; this type of operation allows the plate current to flow for the full 360 degrees of the grid excitation voltage wave and thus gives a very faithful reproduction of the signal wave shape in the output of the amplifier.

Discussion. The following conditions must be satisfied to give good reproduction of the signal wave shape: The grid drive (signal voltage amplitude) must be limited to prevent either the grid from becoming positive at any time or the plate current peaks from being forced into the upper or lower bends of the E_g–I_p characteristic.

2.166. ***Question.*** **What are the characteristics of a class A audio amplifier?**

Answer. Several characteristics of a class A audio amplifier are as follows: Low distortion, low plate circuit efficiency, comparatively low power output, relatively high voltage gain.

2.167. ***Question.*** **What are the advantages of operating two tubes in push-pull rather than in parallel for an audio-frequency amplifier?**

Answer. The main advantage is that distortion due to the second harmonic component is effectively balanced out in a push-pull stage. Other advantages of push-pull over parallel operation of triodes are: greater undistorted power output; reduced hum ripple component with equivalent filter systems; prevention of core saturation of the output transformer; equalization of the output of each tube when excitation is applied.

2.168. ***Question.*** **What will be the effect of incorrect grid bias in a class A audio amplifier?**

Answer. Distortion of the output wave shape.

2.169. ***Question.*** **Why is an audio transformer seldom used in the plate circuit of a tetrode used as an audio-frequency amplifier?**

Answer. The average primary of an audio transformer has an impedance too low for matching the high plate resistance of a tetrode tube. In practice a high resistance or high impedance coil is used in the plate circuit and coupling to the following tube is effected through a condenser, that is, either resistance coupling or impedance-capacitive coupling is used between the output of a tetrode and the next stage.

2.170. ***Question.*** **What are the factors which determine the bias voltage for the grid of a vacuum tube?**

Answer. Some of the factors are as follows:

(*a*) The specific function of the tube, for example, whether used as a power detector, or amplifier and class of operation.

(*b*) The operating d-c voltage on the plate.

(*c*) Grid drive requirements, that is, the range over which the grid potential will swing as determined by the amplitude of the exciting voltage.

2.171. *Question.* **Why are tubes operated as class C amplifiers not suited for audio-frequency amplification?**

Answer. Serious distortion would result because a class C amplifier operating beyond plate current cutoff value gives an output which reproduces less than the full cycle of excitation, in fact, less than one-half of each cycle for a single tube. Also, two tubes in push-pull, class C, would cause large distortion of an audio wave since both the tubes working alternately would still reproduce less than the full audio cycle in the output. In class C operation an oscillatory (r-f) tank circuit connected to the tube's output provides the fly-wheel effect which completes the cycles of r. f., but it is seen that an a-f circuit is not oscillatory.

2.172. *Question.* **Draw a circuit of a "frequency doubler" and explain its operation.**

Answer. See Figure 38.

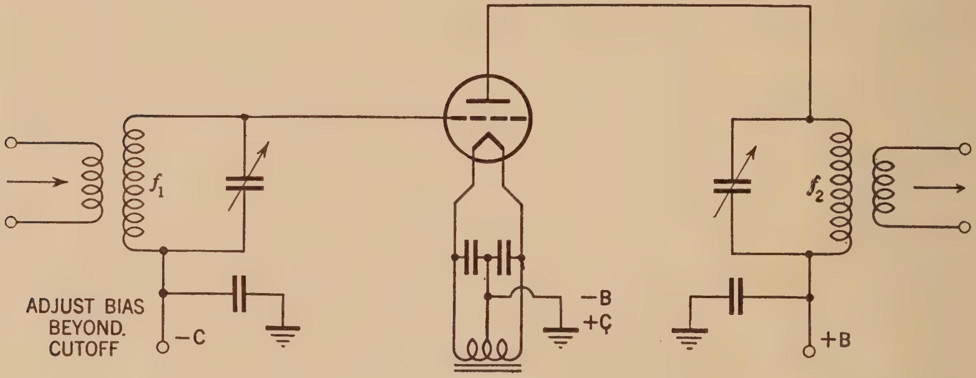


FIG. 38. One type of frequency doubler. Another type employs two tubes with grids in push-pull and plates in parallel.

Explanation. The adjustment of a frequency doubler stage calls for biasing the grid to a value well beyond cutoff, or class C operation which generates a strong second harmonic, and tuning the plate tank to a frequency just twice the excitation frequency applied to the grid.

During a full cycle of the input frequency, f_1, the grid is effective over only a small portion of its positive half cycle of excitation in causing plate current flow. The bias may be adjusted with respect to the signal drive so that plate current flows only during, say, 90 degrees of the grid excitation cycle. This plate current excites the plate tank circuit and the tank being oscillatory continues to oscillate (owing to so-called fly-wheel effect) at the frequency for which it is adjusted, or the doubled frequency. Although there is some decrease in amplitude of each successive alternation in the plate tank circuit, yet this distortion is not serious because in an r-f amplifier, operated class C, with a small angle of plate current flow it is possible to obtain comparatively large plate current peaks.

2.173. *Question.* **For what purpose is a "doubler" amplifier stage used?**

Answer. A "doubler" stage is used when it is desired to obtain a frequency in the plate tank circuit which is twice the excitation frequency applied to the grid. From a practical viewpoint the purpose of a doubler stage is to permit a crystal-controlled oscillator to work at a lower radio frequency so that the crystal itself might be one which is ground to some reasonable thickness, thus making it more rugged and able to withstand shatter and breakdown under the stress of actual operating conditions. A thinner crystal would be required for a higher radio frequency, and naturally it would be more delicate to handle and use. In some transmitters several doubler stages are used to obtain a very high radio-frequency carrier but a crystal oscillator operating at a much lower radio frequency is used.

Another use for frequency doubling is in certain commercial radio-telegraph transmitters of the MOPA type. The master oscillator (a tuned circuit vacuum tube type oscillator) may be adjusted to provide, say, four frequencies for communication, called fundamental frequencies, but the power amplifier acting as a doubler may be retuned so that its plate tank will give the second harmonic, or doubled frequency, of each fundamental, thus making available eight communication frequencies.

2.174. *Question.* How would the loss of radio-frequency excitation affect a class C modulated amplifier using grid-leak bias only?

Answer. The grid would loose its bias in this case and the plate current would rise exceedingly high with no control exercised by the grid over the plate current. In this event overload protection would be depended upon to prevent damage to the tube or component parts of the circuit.

2.175. *Question.* What effect upon the vacuum tube plate current will be noted as the plate circuit resonant frequency of an r-f amplifier is varied?

Answer. With plate circuit tank adjustments on either side of resonance, that is, detuned above and below resonance, the plate current will be high, and as the tank is tuned toward resonance from either side the plate current gradually decreases until it reaches a minimum value at resonance. At resonance the plate current is lowest, or that point where the greatest dip in current fluctuation occurs while tuning.

2.176. *Question.* What types of oscillators are best suited for use in a frequency meter? Describe the desirable characteristics.

Answer. Types of oscillators are crystal-controlled and electron-coupled, the latter generally being accepted as the best suited for use in a frequency meter. For this application the meter should have the following desirable features: excellent frequency stability, or low drift; a good regulated power supply, or battery operation for use as a portable instrument; practical freedom from external circuit influences, for example, when the output is coupled to circuits under measurement; an easy reading scale and visual indicator for resonance; duplication of any frequency setting should be possible with only a reasonable amount of adjustment.

2.177. *Question.* Describe what is meant by "link" coupling and for what purpose(s) is it used?

Answer. A "link coupling" consists essentially of a pair of wires or conductors of desired length terminated at each end by a coil of relatively few turns and with each coil coupled respectively to the main tank circuits of the stages between which the excitation frequency is to be transferred. The two conductors connecting the coils are similar to a transmission line.

Link coupling in transmitter design has several important uses as follows:

(*a*) For the isolation of power source and load electrostatically but not inductively. When one conductor, or one side of the line, in the link circuit is grounded it provides effective electrostatic shielding between stages, which prevents the transfer of parasitic energy from one stage to another.

(*b*) For matching impedances of power source and load.

(*c*) For permitting two adjacent stages to be well separated to prevent crowding and yet allow short leads to be used within the stages. See answer to Question 5.186.

2.178. *Question.* What factors may cause low plate current in a vacuum tube amplifier?

Answer. Possible causes of low plate current are as follows:

(*a*) Low emission filament, or cathode. So-called weak tube due to deactivation of the emitter.

(*b*) Subnormal operating voltages on plate or filament (or heater).

(*c*) Excessive grid bias.

(*d*) In certain classes of amplifier operation a subnormal excitation voltage will give a low plate current reading.

2.179. *Question.* Given the following vacuum tube constants $E_p = 1000$ volts, $I_p = 150$ ma, $I_g = 10$ ma, and grid leak = 5000 ohms, what would be the value of the d-c grid bias voltage?

Answer. The bias voltage would be 50 volts.

Solution: The only values needed for working out this example are grid current and grid-leak resistance. Apply these values directly in Ohm's law to find the voltage. Thus, $E = I \times R = 0.010 \times 5000 = 50$ volts.

Note. Be sure to change milliamperes to the unit ampere before using it in the formula, or 10 ma = 0.010 ampere.

2.180. *Question.* Explain how you would determine the value of cathode bias resistance to provide correct grid bias for any particular amplifier.

Answer. Since the voltage across the bias resistor will be the grid bias we need to know the amount of current which will flow through this resistor and its resistance value, or $R = E/I$. For a triode the current is the plate current and for a tetrode both plate and screen-grid currents. Ohm's law is used to find the value of the bias resistance for a tube operating as a linear amplifier as follows:

$R_c = \dfrac{E_c}{I_{bo}}$, where E_c = d-c voltage desired on grid (in volts),
I_{bo} = total d-c emission current in amperes (for a triode this is the plate current),
R_c = cathode bias resistor (in ohms).

Note. When the tube is used as a biased detector, the formula still holds except that I_{bo} is the d-c emission current under conditions of no signal.

2.181. *Question.* Under what load conditions will a vacuum tube have the highest ratio of power output to plate circuit d-c input?

Answer. This is equivalent to asking "Under what load conditions will the plate efficiency be highest?" It will be highest when the load chosen is such that the tube operates only in the linear region of its characteristic. Since this ratio gives the plate efficiency then a very high load impedance compared with the plate resistance of the tube would suggest the answer to the question, but under such conditions the tube might be inadequately loaded.

2.182. *Question.* **Under what load conditions will a vacuum tube produce its greatest output?**

Answer. Assuming a linear characteristic, the greatest power output occurs when the load impedance, or resistance, is equal to the plate resistance of the tube, or $R_L = r_p$. However, if the characteristic is nonlinear but only to the extent that the second harmonic must be considered, then, for single tube operation, maximum power output occurs when the load resistance or impedance is about twice the plate resistance of the tube.

2.183. *Question.* **What is the chemical composition of the active material composing the negative plate of a lead-acid type storage cell?**

Answer. The negative plate is pure metallic lead (Pb) in spongy form.

2.184. *Question.* **What is the chemical composition of the active material composing the negative plate of an Edison type storage cell?**

Answer. The negative plate is powdered iron oxide (FeO_4), which is reduced to metallic iron (Fe) when first charged, and a small percentage of oxide of mercury (HgO) is mixed in to increase the conductivity.

2.185. *Question.* **What is the composition of the active material composing the positive plate of a lead-acid type storage cell?**

Answer. The active material in the positive plate is lead peroxide (PbO_2), also called lead dioxide or litharge. (See discussion under Question 2.202.)

Note. The formula for charge and discharge cycles of a lead-acid cell follows:

$$2H_2SO_4 + Pb + PbO_2 \underset{\text{Discharge}}{\overset{\text{Charge}}{\leftrightarrows}} PbSo_4 + PbSO_4 + 2H_2O$$

2.186. *Question.* **How does a primary cell differ from a secondary cell?**

Answer. The materials in a **primary cell** are used up or decomposed in the chemical reaction when current flows and therefore this type cannot be recharged. A **secondary cell** is a storage cell which can be recharged after being discharged by reversing the chemical reaction to make the cell ready for use again.

2.187. *Question.* **What is the chemical composition of the active material composing the positive plate of an Edison type storage cell?**

Answer. The active material in the positive plate consists of nickel hydrate alternating with layers of very thin flakes of pure nickel, the latter being added to increase the electrical conductivity. The nickel hydrate changes to *nickel oxide* when first charged.

Note. On discharge of an Edison cell the positive plate composed of nickel oxide (NiO_2) changes to a *lower* oxide of nickel (Ni_3O_4) in which some free oxygen (O) is given off, and also oxygen unites with the metallic iron (Fe) composing the negative plate to form iron oxide (FeO_4). On charge the positive plate is restored to the higher oxide of nickel and the negative plate to metallic iron.

2.188. *Question.* **What is the chemical composition of the electrolyte used in an Edison type storage cell?**

Answer. The electrolyte is a 21 per cent solution of potassium hydrate, KOH, in pure distilled water mixed with a small amount of lithium hydrate, and having a specific gravity of approximately 1.200.

2.189. **Question. What is the chemical composition of the electrolyte of a lead-acid storage cell?**

Answer. The electrolyte is sulphuric acid, H_2SO_4, diluted with pure distilled water.

2.190. ***Question.*** **Why is a 45 volt dry cell "B" battery generally considered unsatisfactory for use when the terminal voltage has fallen to approximately 36 volts?**

Answer. The low voltage indicates that the internal resistance of the battery is becoming very high and the current it is capable of supplying in the load circuit will fall off very rapidly. This condition also means that the terminal voltage of the battery will drop very rapidly from then on if kept in service.

2.191. ***Question.*** **What is "polarization" as applied to a primary cell, and how may its effect be counteracted?**

Answer. The normal chemical action of a primary cell when being used causes "polarization," which is the forming of hydrogen gas on the surface of the positive electrode; the gas acts as an insulator. Some material is included in the cell to provide oxygen which will combine with this hydrogen to form water; manganese dioxide is the *depolarizing* agent used in most dry cells. Another type of dry cell battery, called "air cell" battery, uses a special porous form of carbon capable of taking in oxygen from the atmosphere, which retards the effects of polarization and thus increases the useful life of the cell.

2.192. ***Question.*** **Name four causes of a decrease in capacity of an Edison type storage cell.**

Answer. Four causes of decrease in capacity are: subjecting the cell to frequent continued overheating, using old electrolyte, using weak electrolyte, and refilling the cell with impure water during regular servicing.

2.193. ***Question.*** **What causes heat to develop within a storage cell under charge or discharge conditions?**

Answer. The heat developed is due to two causes, one being the normal chemical actions, and the other, the I^2R loss which always results when a current flows through a resistance, the internal resistance of the cell. In a storage cell the *internal resistance* consists of the plates, electrolyte, or any other materials through which the current must flow in going from one terminal to the other within the cell.

2.194. ***Question.*** **How should sulphuric acid and water be mixed, if it becomes necessary to mix it in order to replace lost electrolyte?**

Answer. Mix the solution only in a glass, earthenware, or lead receptacle. Place the quantity of distilled water in the receptacle and pour the acid slowly into the water—never the water into the acid, because the chemical action of this combination is rather violent and might result in body burns due to the steam from the water throwing part of the acid out of the receptacle. Allow the mixture to cool before taking its specific gravity and before using it in the cell. A relatively high specific gravity, about 1.280 to 1.300, is obtained by adding one part of commercially pure concentrated sulphuric acid to four parts of distilled water. A mixture of one part acid to about five parts water will give a low specific gravity, about 1.220, for use in heavy-duty batteries made to handle large current drains over long periods without undue heating.

2.195. *Question.* How may a dry cell be tested to determine its condition?

Answer. A standard 6-inch dry cell may be given a *momentary* short-circuit test, using a low resistance ammeter for the purpose, and the cell in good condition should show a reading of at least 18 amperes. Smaller dry cells are to be checked on a normal load, using a voltmeter to note the drop in terminal voltage. A dry cell checked on open circuit with a voltmeter should be discarded when the voltage drops to about 20 per cent of the normal rated voltage.

2.196. *Question.* What will be the result of discharging a lead-acid storage cell at an excessively high current rate?

Answer. The ampere-hour capacity of the storage cell will be reduced below its minimum normal rating if discharged at an excessively high rate; the terminal voltage of the cell will drop rapidly; excessive heat will be generated.

2.197. *Question.* What is the approximate fully charged voltage of an Edison cell?

Answer. The charged voltage is about 1.2 volts.

Discussion. Other practical values for this type of cell are discharged voltage 0.9 volt and charging voltage 1.5 to 1.85 volts. These values vary under different conditions of rate of charge or discharge, temperature, specific gravity of the electrolyte, type of cell, and age of battery.

2.198. *Question.* A 6-volt storage battery has an internal resistance of 0.01 ohm. What current will flow when a 3-watt, 6-volt lamp is connected?

Answer. A current of 0.49 ampere will flow.

Solution: First apply the watt formula in terms of R to find the lamp's resistance. Thus $R = \frac{E^2}{W} = \frac{6^2}{3} = \frac{36}{3} = 12$ ohms, or resistance of the lamp. The total circuit resistance is the sum of the lamp resistance and internal resistance of the battery, or $0.01 + 12 = 12.01$ ohms. Now to find the current flow apply Ohm's law for current, or $I = \frac{E}{R} = \frac{6}{12.01} = 0.49$ ampere.

2.199. *Question.* What is the approximate fully charged voltage of a lead-acid cell?

Answer. The voltage is approximately 2.1 volts.

2.200. *Question.* Why is low internal resistance desirable in a storage cell?

Answer. A low internal resistance in a cell under load gives a low internal voltage drop, and this is desirable because it allows a higher terminal voltage and greater current to flow in the load circuit.

2.201. *Question.* What is "local action," and how may its effects be counteracted?

Answer. Any impure and foreign metals which might be present in the plates of a storage cell, even to a limited extent, causes "local action" to set in. The contact of these dissimilar metallic particles with the plate material causes a chemical action which produces a current that slowly eats away the plates and builds up sulphation. This is known as "local action" and in time decreases the e.m.f. of the cell.

Local action may be almost entirely prevented by keeping the cell in good condition through observing proper charge and discharge rates and keeping the battery on trickle charge when not in use.

2.202. *Question.* What is meant by the term "sulphation" as applied to a lead-acid storage cell?

Answer. The formation of lead sulphate on both sets of plates in a lead-acid cell is called "sulphation."

Discussion. When the expression *sulphated battery* is used it generally indicates that the battery has been abused in service by allowing the sulphation to build up heavy and thick, thus making it difficult if not impossible to remove it by ordinary charging methods. If after each charging period some sulphate remains on the plates and this practice of undercharging is continued, the terminal voltage will be subnormal under load and the ampere-hour capacity will be lowered.

The chemical action which causes sulphation is as follows: During the discharge period of the cell the sulphuric acid, H_2SO_4, breaks up into hydrogen, H, and sulphate, SO_4. The sulphate combines with the lead in each set of plates, forming the compound lead sulphate, $PbSO_4$, and the hydrogen unites with the oxygen of the lead dioxide, PbO_2, to form water in the solution. As the discharge continues, more sulphate replaces the active materials of both plates, which lowers the e.m.f. of the cell, and additional water is formed, which gradually weakens the electrolyte.

2.203. *Question.* How may the condition of charge of an Edison cell best be determined?

Answer. The condition of charge can be determined by taking a terminal voltage check with a d-c voltmeter of low range. In addition to a voltmeter, many installations for charging Edison batteries provide an ampere-hour meter for practical servicing because it shows directly the ampere-hour capacity of the battery.

Note that a hydrometer will **not** serve for checking an Edison cell because the specific gravity of the electrolyte in this type does not change sufficiently to be used as an indication of charge or discharge conditions.

2.204. *Question.* If the charging current through a storage battery is maintained at a normal rate but its polarity is reversed, what will result?

Answer. The answer is given for both types of storage batteries as follows:

Lead-acid type battery. Charging in the wrong direction reverses the reactions in the negative and positive plates, and after a time a voltmeter would show reversed polarities at the terminal posts. However, if the reversed current flow is not allowed to continue too long, or the current is not sufficiently high to cause overheating, such reversal will not cause permanent damage, but in any event, it is to be avoided. To recharge the battery it would be necessary to remove the reversed charged condition of the plates by discharging the battery completely and then giving it a prolonged charge at a reduced rate.

Edison type battery. Charging in the wrong direction would cause this type of battery to discharge rapidly, but it could be recharged by charging in the correct direction. No permanent damage would result from the attempted reversal charging except a temporary lowering of the ampere-hour capacity of the battery.

2.205. *Question.* What are the effects of sulphation?

Answer. The following are effects due to sulphation: Forming of sulphate causes both sets of plates to become more and more alike, which has the effect of putting the cell in a partially discharged condition, thus lowering the ampere-hour capacity; terminal voltage of the cell is greatly lowered under load; internal resistance of the cell is increased.

Discussion. The sulphate, as it slowly forms and fills in the pores, retards the free circulation of the acid into the interior portions of the plate material. There comes a time when the acid cannot get into the plates sufficiently fast to maintain the normal chemical action, so the battery becomes less active, as indicated by the rapid dropping of the terminal voltage.

2.206. *Question.* How may the state of charge of a lead-acid storage cell be determined?

Answer. The condition of charge of a lead-acid cell may be determined by taking a specific gravity reading with a **hydrometer.**

Discussion. A voltmeter is generally provided with shipboard emergency power supply systems which use heavy-duty storage batteries, to give indications of practical use while the battery is under load. In regular servicing, however, the cells are individually checked with a hydrometer. A "pilot" cell may be used when daily readings are required. A pilot cell is the cell which is selected for taking gravity readings over a period of time so that all cells in a battery need not be checked daily, the pilot cell being rotated periodically.

2.207. *Question.* With respect to its use in connection with d-c motors and generators, what is the meaning of the term "neutral position"?

Answer. "Neutral position" is the position in which the brushes are set with relation to the armature coils undergoing commutation in order to prevent sparking.

Discussion. Sparking results when brushes are improperly set with respect to the neutral axis. When current flows in the armature of a generator the neutral axis shifts in the direction of rotation but in a motor it shifts against the direction of rotation.

2.208. *Question.* Why is laminated iron or steel instead of solid metal generally used in the construction of the field and armature cores of motors and generators?

Answer. An iron core made of laminations reduces eddy currents; and in turn less heat is generated, which keeps down the power losses in such machines.

Discussion. A solid mass of iron would heat up excessively because eddy currents would build up unrestricted throughout the material. When eddy currents are confined to the individual sheets or laminations they can reach only comparatively small values. The power used in generating eddy currents, also known as Foucault currents, is a total loss since the heat in this case serves no useful purpose.

2.209. *Question.* What is meant by "regulation" of a generator?

Answer. The percentage of change in the output voltage of a generator between no-load and full-load conditions compared to the full-load voltage is the "regulation." The formula below gives this relation, or

$$\text{Regulation (in per cent)} = \frac{E_{\text{max}} - E_{\text{min}}}{E_{\text{min}}} \times 100$$

2.210. *Question.* What is the purpose of "commutating poles" or "interpoles" in a d-c motor?

Answer. "Interpoles" are used to provide sparkless commutation without making it necessary to shift brushes to obtain this condition.

Discussion. Interpoles of proper polarity are located between the main poles. The interpole coils are connected in series with the armature coils so that the same current flows through both windings, thus setting up opposing fluxes which cancel the effects of self-induction in the armature coils, one of the causes of sparking.

2.211. *Question.* How may the output voltage of a separately excited a-c generator, at constant output frequency, be varied?

Answer. A generator field rheostat (variable resistance) connected in series with the generator field is the practical means used for varying the output voltage. Increasing the resistance lowers the field current and decreases the voltage, whereas, decreasing the resistance increases the field current and raises the voltage.

2.212. *Question.* If the field of a shunt wound d-c motor were opened while the machine was running under no load, what would be the probable result(s)?

Answer. The armature speed would build up almost instantly and tend to race away at an exceedingly high speed. This increased speed of rotation might cause damage to the machine unless protective devices operate to remove line voltage from the armature. The absence of the normal counter e.m.f., due to the loss of the field flux, allows excessive current to be drawn by the armature and if unchecked, it might burn out the coils. It is possible for a racing armature to tear itself apart, or explode, as it is said.

2.213. *Question.* Name four causes of excessive sparking at the brushes of a d-c motor or generator.

Answer. A number of possible causes of excessive sparking are given under headings which suggest the seat of the trouble as follows:

(*a*) Brushes:
  Brushes improperly set with respect to neutral position.
  Improper spring tension; tension too light.
  Brush stuck in holder.
  Worn brushes; improper fit with commutator.
(*b*) Commutator:
  Dirty commutator.
  High bars.
  Commutator out-of-round.
(*c*) Armature:
  Coil open-circuited.
(*d*) Operation of Machine:
  Overloading of motor or generator.

2.214. *Question.* What is the purpose of a commutator on a d-c motor? On a d-c generator?

Answer. A commutator functions essentially as a mechanical rectifier. In a d-c motor the commutator converts the d-c voltage applied at the brushes to a.c. in the armature, which keeps the current in the coils reversing periodically to cause motion. In a d-c generator the alternating current in the armature is changed by the commutator to give d.c., or a unidirectional flow in the load connected to the brushes.

2.215. *Question.* **What is meant by "counter e.m.f." in a d-c motor?**

Answer. While a motor armature rotates there is a generator action going on inherently in the armature windings because an e.m.f. is induced in the conductors which is in opposition or counter to the line voltage which causes the rotation. Owing to this "counter e.m.f." the actual voltage across the armature is much less than the line voltage.

2.216. *Question.* **What determines the speed of a synchronous motor?**

Answer. The *frequency* of the a-c voltage applied to the motor determines the speed.

2.217. *Question.* **Describe the action and list the characteristics of a shunt wound d-c motor.**

Answer. Principle of Action. The counter e.m.f. in the armature of a shunt wound d-c motor will decrease by the slowing down of the armature when the load is applied; however, the field excitation will remain unchanged. Therefore, under such conditions of decreased counter e.m.f. the line voltage sends a larger current to the armature, which tends to increase the speed and compensate for the reduction in speed caused by the load. In determining the speed at any given load, practical use is made of the fact that the counter e.m.f. in the armature depends upon field strength and armature speed.

Characteristics. A shunt type d-c motor has fairly good speed-load characteristics. It is sometimes called a constant speed machine, although it is not quite constant but falls off slightly with increased load. If an unchanging load is applied the speed will drop somewhat at first, but thereafter it will remain steady at the reduced speed. The two main electrical characteristics are low starting torque and nearly constant speed regulation. A physical characteristic of this type of motor is the use of a field having comparatively high resistance compared to the armature.

2.218. *Question.* **Describe the action and list the main characteristics of a series d-c motor.**

Answer. Principle of Action. In a series type motor the field strength is affected by the armature speed since the same current flows through both the field and armature coils in series. Therefore, the slowing down of the armature for any reason will increase the flux set up by both windings, field and armature, which has the effect of increasing the torque. Decreased speed lowers the counter e.m.f. and allows more current to flow in the field and armature. Removing the load would cause the armature to race, and for this reason the load is kept applied to all series d-c motors; they are designed to start under load. Motors of this type are used in applications where a large starting torque is required, such as electric street cars.

Characteristics. The main characteristics of a series d-c motor are large starting torque which permits quick starting; the torque increases at lower speeds; the speed depends on the load and decreases with increase of load.

2.219. *Question.* Describe the action and list the main characteristics of a series d-c generator.

Answer. In a series type generator the load current flows through both the armature and field windings in series; changes in load current affect the field strength and in turn the output voltage. If the load current increases the generated voltage increases and the internal voltage drop in the armature also increases. This type operates satisfactorily on a constant-current line, such as in certain types of lighting circuits in which all of the lamps are in series and the current through them is kept appreciably steady.

Characteristics. The main electrical characteristics are that the voltage rises with increase of load and lowers with reduction of load; the voltage depends entirely on the load. A physical characteristic is that the field winding is made up of comparatively few turns of heavy wire to carry full line current.

2.220. *Question.* To obtain an output frequency of 60 cycles per second, a 6-pole alternator must be driven at what number of r.p.m.?

Answer. The armature must turn over at 1,200 r.p.m.

Solution: The basic formula to find frequency is

$$f = \frac{N}{2} \times \frac{\text{r.p.m.}}{60} = \frac{N \times \text{r.p.m.}}{120}, \quad \text{where } f = \text{cycles per second,} \quad N = \text{number of poles.}$$

Hence, to find the r.p.m. we write this formula another way, or

$$\text{r.p.m.} = \frac{f \times 120}{N} = \frac{60 \times 120}{6} = 10 \times 120 = 1{,}200$$

2.221. *Question.* Describe the action and list the main characteristics of a self-excited shunt wound d-c generator.

Answer. The self-excited shunt field is connected across the brushes so that some residual magnetism must be present in the field poles to permit a small e.m.f. to be generated at the time of starting. The initial e.m.f. upon starting sends a small current through the field which builds it up, and in turn a larger voltage is generated. When the load is applied and current is drawn through the armature there is an internal voltage drop which tends to reduce the voltage at the brushes, and hence the field gets a reduction in voltage and current, which in turn cuts down the output voltage. However, small changes in current through the shunt field, consisting of many turns of fine wire, have only a slight effect on the output voltage. A rheostat in series with the field will permit control of the output.

Characteristics. The main electrical characteristic is fairly good voltage regulation, so that such machines are generally classified as constant potential generators. Another is that in machines of this type the total armature current is divided into the small portion that flows in the field and the larger current that flows in the line.

2.222. *Question.* Describe the action and list the main characteristics of a flat-compounded d-c motor.

Answer. A flat-compounded d-c motor, or differential compound motor, has two fields, one connected in shunt and the other in series with the armature, with the respective field fluxes bucking each other. Hence, if the load on the motor is increased the resultant total field will be weakened because the armature in tending to slow down reduces the counter e.m.f. which allows a larger current to flow in the series field. A stronger series field weakens the total field flux, which tends to increase armature speed; in this action the field excitation is varied by changes in load and armature current; the shunt field remains constant since it is energized from the line.

Characteristics. The main characteristics are low starting torque and practically uniform speed over a wide range of load conditions. This type of motor is used widely for motor-generator sets in commercial radio transmitters where constant speed characteristics are a requirement.

2.223. ***Question.*** **What is the output frequency of a generator having 10 poles and revolving at 1,200 r.p.m.?**

Answer. The frequency is 100 cycles.

Solution: Applying the frequency formula and inserting known values, we have

$$f = \frac{N}{2} \times \frac{\text{r.p.m.}}{60} = \frac{10 \times 1{,}200}{120} = 100 \text{ cycles}$$

2.224. ***Question.*** **How may the direction of rotation of a shunt wound d-c motor be reversed?**

Answer. The direction of rotation in this type motor may be reversed by reversing connections at the field terminals, or by reversing connections at the armature. That is, either one pair of connecting leads or the other may be reversed from their present connections, but both pairs must not be reversed together.

2.225. ***Question.*** **Why are series motors not used for radio motor-generator sets?**

Answer. A series motor has a variable speed characteristic under variable load, which makes it unsuited for radio motor-generator sets because the regulation would be exceptionally poor. Furthermore, such machines must operate with a load always kept applied, which would be impracticable in radio power supply applications.

2.226. ***Question.*** **Why is carbon commonly used as a brush material?**

Answer. Carbon is a relatively soft material which can be easily sanded to fit a commutator to give good electrical contact. Although a soft material, carbon has good wearing properties and requires infrequent replacement, which makes it desirable from a service standpoint. The heat generated at the point of contact owing to friction is not objectionable when proper brush tension is maintained. The heat set up by a carbon brush is far less than for a metal brush under similar conditions of brush contact area. A carbon brush gradually wears away without any harmful effects on a commutator, such as scoring, because of the polishing action at high speeds; the carbon helps to keep the commutator surface in good condition. Other points to mention are that carbon can be readily worked into different shapes and is relatively inexpensive.

2.227. ***Question.*** **If a self-excited d-c generator failed to build up to normal output voltage when running at normal speed, what might be the cause and how could it be remedied?**

Answer. The absence of residual magnetism in the field poles might be the cause. A self-excited d-c generator depends upon this residual magnetism to produce a small voltage at the time of starting, which soon builds up to provide a normal field. The remedy is to insert a source of d-c voltage in series with the field, such as a battery, to send current through the winding, which will remagnetize the iron sufficiently for starting. The exciting source should be removed later and the field circuit closed to give it continuity.

2.228. ***Question.*** **A transformer having a center-tapped secondary is used with a full-wave rectifier with the transformer center-tap for the common negative return; if the transformer was connected for full-wave bridge rectification, what would be the effect upon the output voltage?**

Answer. The output voltage would be doubled by the new connection. The ripple frequency in the output voltage wave would be the same in both cases.

2.229. ***Question.*** **If a high voltage rectifier system was changed from a full-wave, center-tapped transformer connection to a bridge connected, full-wave rectifier system using the same high voltage transformer, what change in the filter components would be necessary?**

Answer. Filter components rated at twice the former voltage would be required, and other considerations would have to be taken into account, such as any possible increase in load current (power output) which would affect the rating of the chokes. Also, filter capacitors of smaller capacitance rating could be used at the higher voltage.

2.230. ***Question.*** **List the main advantages of a full-wave rectifier as compared to a half-wave rectifier.**

Answer. The main advantages of a full-wave rectifier over the half-wave type are a more constant d-c potential using a comparatively smaller filter system and a lower order of hum level. The advantages mentioned are due in the main to a full-wave rectifier giving twice the number of d-c pulsations (twice the ripple frequency) resulting in a smoother d-c output wave.

2.231. ***Question.*** **Using a plate transformer having a secondary voltage of 500 volts r.m.s. in a single phase half-wave rectifier working into a condenser input filter, what would be the minimum allowable d-c working-voltage rating for the filter input condenser?**

Answer. 2,000 volts is a safe voltage rating. To answer this question, first determine the peak voltage at which the condenser will be charged, or $500 \times 1.41 = 705$ volts, peak voltage. Then ensure ample protection from breakdown.

2.232. ***Question.*** **A single phase power transformer, with secondary center tapped, has total secondary voltage of 2,000 volts r.m.s. When used in a full-wave rectifying circuit and condenser input filter, the filter input condenser should have what continuous d-c working-voltage rating?**

Answer. 4,000 volts is a safe voltage rating. First determine the peak voltage at which the condenser will be charged. Because of the center-tapped secondary the total secondary voltage, or 2,000 volts, is divided in half, or 1,000 volts, which is multiplied by 1.41, giving 1,410 volts, peak voltage. A safe voltage rating of the condenser under continuous d-c working conditions would be 4,000 volts.

2.233. ***Question.*** **Why may a transformer not be used with direct current?**

Answer. Direct current sets up a steady flux which will not cause induced voltage effects in the secondary; it requires a varying current in the primary to get a secondary voltage. The transformer operates on the principle of electromagnetic induction.

2.234. ***Question.*** **Draw a simple schematic diagram of a half-wave, three-phase rectifier system.**

Answer. See Figure 39.

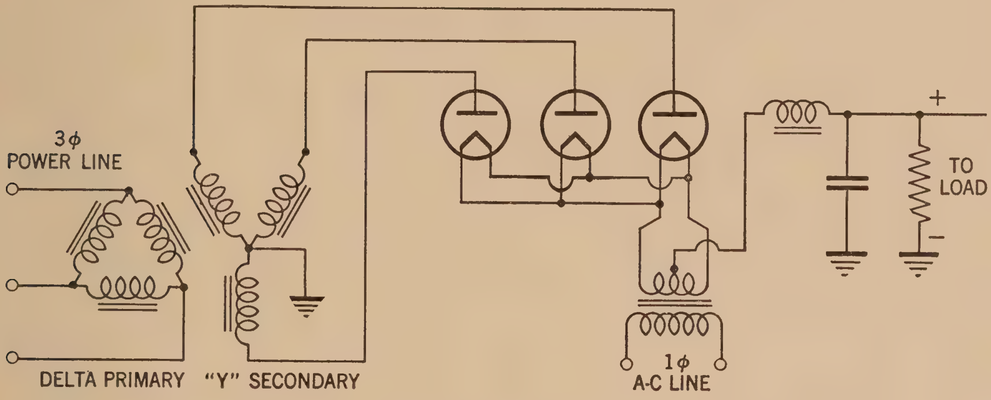


FIG. 39. Half-wave three-phase rectifier with choke-input filter.

2.235. ***Question.*** **What are the primary advantages of a high-vacuum rectifier as compared with the hot-cathode mercury-vapor rectifier?**

Answer. The primary advantages of a high-vacuum rectifier over a hot-cathode mercury-vapor type are listed as follows:

(*a*) Not readily subject to breakdown due to flash-back; high-vacuum types have a higher maximum peak inverse voltage rating.

(*b*) More rugged; under improper working conditions the filament is not subject to complete loss of emission because in the high-vacuum type ionization principles are not involved in the action.

(*c*) Operation is much quieter where conduction in a tube is through a high vacuum.

(*d*) A condenser input to the filter can be used with its accompanying advantages.

(*e*) Higher output ratings are generally more possible.

(*f*) Cooling requirements are less stringent; high-vacuum rectifiers can be operated at comparatively high temperatures without danger because over-ionization effects are not involved as in mercury-vapor tubes.

2.236. ***Question.*** **What are the primary characteristics of a gas-filled rectifier tube?**

Answer. The primary characteristics of a gas-filled rectifier are listed as follows:

(a) Low internal resistance; low *IR* drop.

(*b*) High current output; the negative space charge being effectively removed during conduction allows practically full electron emission at the filament to be drawn as plate current.

(*c*) The current rise is steep immediately after the tube begins conducting on each cycle, which results in a noisy output unless effective means are provided to cope with this disadvantage.

(*d*) Peculiar colored glow, greenish-blue, indicates normal action.

(*e*) At low filament temperatures the filament is bombarded and excessive conditions will cause permanent damage by loss of its emission properties, that is, complete deactivation occurs.

(*f*) Comparatively low inverse peak voltage rating; operating a gas-filled rectifier at excessive high temperatures causes overionization, which makes flash-back easily possible.

2.237. *Question.* What are the primary advantages of a mercury-vapor rectifier as compared with the thermionic high-vacuum rectifier?

Answer. The primary advantages of a mercury-vapor rectifier are as follows:

(*a*) Low internal voltage drop; about 15 volts.

(*b*) Practically perfect voltage regulation; this is because the voltage drop in the tube remains about 15 volts regardless of the amount of current drawn under normal conditions, whereas voltage drop in a high vacuum varies with load.

(*c*) Filament requirements are less for a given output than in the case of the high-vacuum type; practically all of the emission at the filament is useful in supplying output current, which is possible owing to cancellation of the negative space charge in a mercury-vapor tube.

(*d*) In tubes of comparative ratings the mercury-vapor type runs cooler and the need for special forced air circulation or water cooling is not usually a consideration. However, the operating temperature limits are rather critical in a mercury-vapor tube and if allowed to go much above 115° F. permanent damage might result owing to overionization; therefore adequate forced circulation of air under some conditions might be necessary.

2.238. *Question.* Why is it desirable to have low resistance filter chokes?

Answer. A low resistance choke allows a higher voltage to be obtained from the output for the reason that the d-c component flowing in a low resistance gives a low voltage drop.

2.239. *Question.* Why is it necessary to use choke input filter systems in connection with mercury-vapor rectifier tubes?

Answer. A choke input lowers the peak voltage appearing across the tube and thus protects the tube from possible danger of flash-back.

2.240. *Question.* What are the primary characteristics of a choke input filter?

Answer. The primary characteristics of a choke input filter are as follows:

(*a*) Lower peak voltages due to current surges.

(*b*) Lower comparative voltage at the filter output.

(*c*) Good voltage regulation; this is because the output of the rectifier tubes works into a choke which has a steadying effect on the current.

2.241. *Question.* What are the primary characteristics of a condenser input filter?

Answer. The primary characteristics of a condenser input filter are as follows:

(*a*) Voltage at the filter output is higher than with choke input.

(*b*) Higher peak voltages build up across the filter input.

(*c*) Voltage regulation is only fair and not nearly as good as with choke input.

2.242. *Question.* What is the primary purpose of a "swinging choke" in a filter system?

Answer. The primary purpose of a "swinging choke" in a filter system is to maintain the necessary inductance, or impedance, at the rectifier output for widely changing load conditions. The inductance of the choke changes with the d-c component; for example, as the direct current increases the voltage drop across the coil decreases, which tends to stabilize the effect in a filter such as might be used in a class B amplifier power supply. See answer to Question 5.108.

2.243. *Question.* Why does the output of a d-c generator generally require less filtering than the output of a rectifier system?

Answer. A generator produces *overlapping* pulses of d-c voltage in which the amplitude of the ripple or a-c component is small when compared with the large amplitude of rectified a-c pulsations of a rectifier system.

2.244. *Question.* When filter condensers are connected in series, resistors of high value are often connected across the terminals of the individual condensers. What is the purpose of this arrangement?

Answer. The purpose of connecting a resistor across each condenser unit is to protect the condenser from being subjected to excessive high voltage which might damage it. If there is any variance in the internal resistances of condensers in a series bank the one with the highest internal resistance will have the highest voltage applied to it. Also, the a-c component will cause the peak voltage to be highest across the condenser of lowest capacitance. The resistors being in series and connected across the line form practically a voltage divider which allows the line voltage to be distributed proportionally across the individual condensers to keep them working within safe limits.

2.245. *Question.* Draw a diagram of a bridge type, single phase rectifier employing mercury-vapor type tubes and connected to a choke input, two-section filter system, including a bleeder resistance.

Answer. See Figure 40.

2.246. *Question.* Draw a diagram of a full-wave, single phase rectifier employing thermionic vacuum tubes, connected to a condenser input, two-section filter system, and including a bleeder resistance.

Answer. See Figure 41.

2.247. *Question.* Draw a diagram of a half-wave rectifier system employing thermionic rectifier tubes and a two-section, condenser input filter system.

Answer. See Figure 42.

2.248. *Question.* What is the primary purpose of a "bleeder" as used in a filter system?

Answer. A bleeder in a filter system prevents voltage surges and dangerous

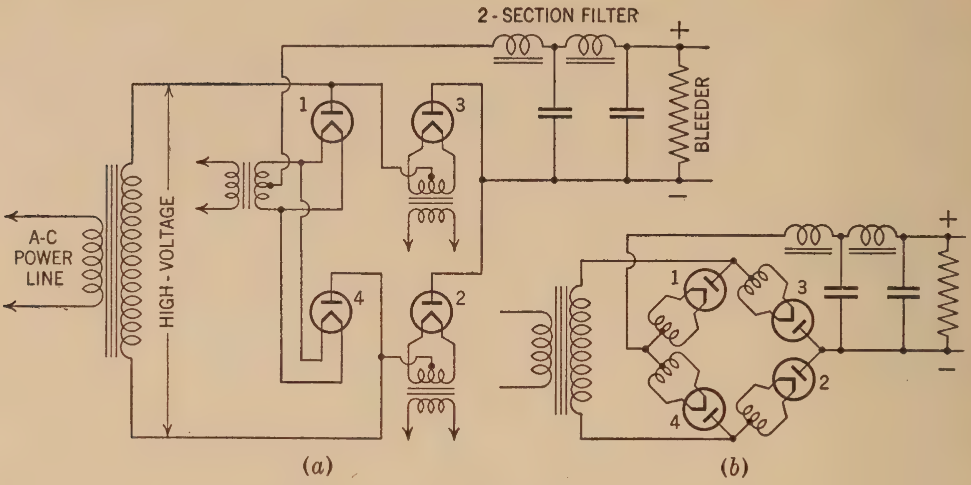


FIG. 40. Full-wave bridge-type rectifier with choke-input filter.

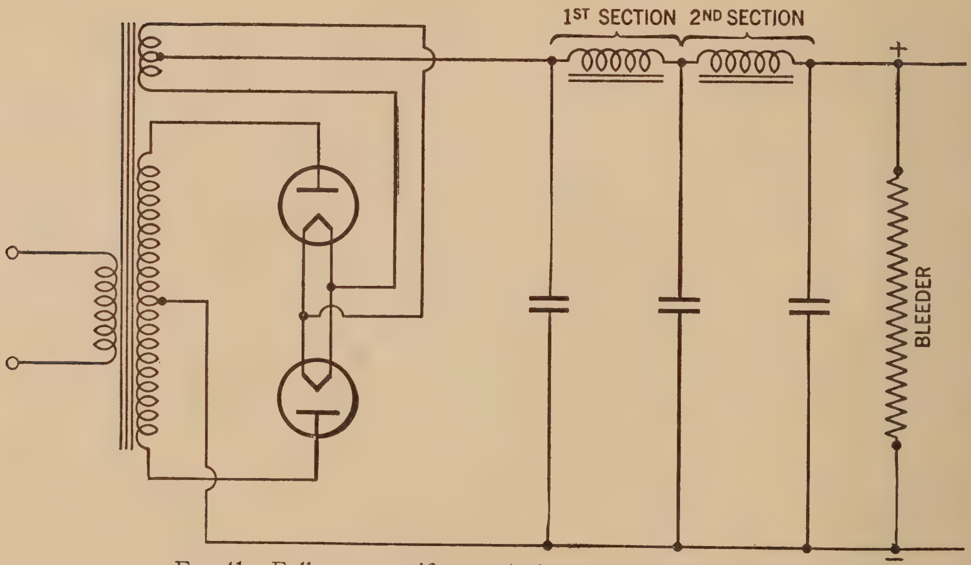


FIG. 41. Full-wave rectifier employing condenser input filter.

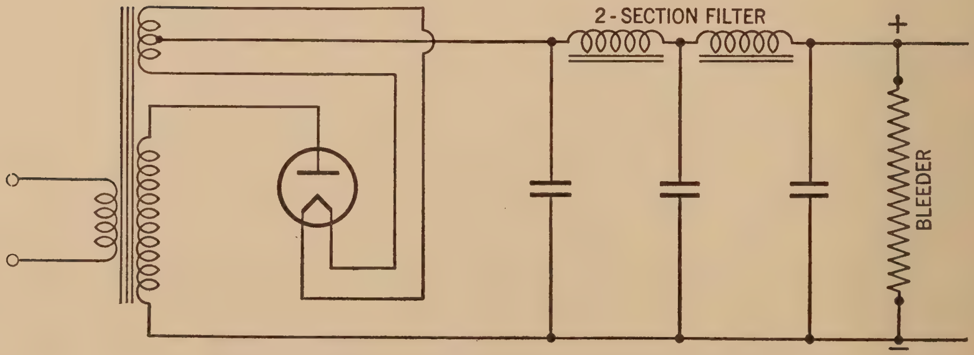


FIG. 42. Half-wave rectifier with condenser input filter.

peak voltages from developing during reduced load or no-load conditions on a rectifier. A small fixed load is kept applied at the rectifier output by a bleeder. Another advantage from its use is improved regulation, although the useful voltage at the rectifier output is lowered somewhat by the load presented by the bleeder. Also, filter condensers can discharge into a bleeder under no-load conditions, or when the rectifier is shut down, which removes a hazard to personnel working on the equipment; otherwise large filter condensers could hold their charge for some time after a rectifier is placed out of operation.

2.249. *Question.* If the frequency of the supply source is 60 cycles, what is the output ripple frequency of a three-phase, full-wave rectifier?

Answer. 360 cycles.

Calculation: Since every half-cycle of each phase gives a pulsation, or rectified wave, then it follows that 2 rectified waves per phase multiplied by 3 phases multiplied by 60 cycles per second equals 360 cycles, the ripple frequency.

2.250. *Question.* If the frequency of the supply source is 60 cycles, what is the output ripple frequency of a single phase rectifier, full wave?

Answer. 120 cycles.

Calculation: Each cycle produces 2 pulsations, or rectified waves, hence 2 rectified waves per phase × 1 phase × 60 cycles per second = 120 cycles per second.

2.251. *Question.* If the plates of a full-wave high vacuum rectifier tube became red hot during operation, what may be the cause(s) of this condition?

Answer. Several causes of a high vacuum rectifier tube running red hot are excessive load, which may be due to improper adjustments of circuits receiving power from the rectifier, or a shorted filter condenser or short somewhere in the output, or the trouble may be in the tube itself; for example, formation of gas might make the tube "soft."

2.252. *Question.* List the primary characteristics of a high voltage plate supply as compared with a low voltage plate supply, considering the capacity of the filter condensers required to provide a given degree of filtering.

Answer. For condenser input pi (π) filters or for simple combinations involving only a condenser across the load, the capacitance required varies as the d-c load current and inversely as the d-c output voltage. Accordingly, for the same d-c output power, a high voltage supply with relatively low current would require much less capacitance for a given degree of filtering than would a low voltage supply.

Discussion. If the filter is a choke input type, then for a given type of rectification (half-wave, full-wave, bridge type, etc.) the product of $L \times C$ depends solely upon the allowable percentage ripple referred to the output voltage. On the other hand the minimum value of L varies inversely with the d-c output current. Low voltage rectifiers usually have a higher d-c output current than high voltage types. Accordingly the minimum L can be smaller and for this reason the value of C to accomplish a given amount of filtering must be higher in low voltage rectifiers.

2.253. *Question.* How may radio-frequency interference from gaseous rectifier tubes be minimized?

Answer. Shielding of the rectifier tube with the shield grounded, inserting an r-f choke in the plate lead close to the plate terminal of the tube socket, and the use of a buffer condenser connected from plate to ground are various means found in practice for minimizing r-f interference from a gaseous type rectifier tube.

2.254. *Question.* **What is the primary purpose for having choke input to a filter when using mercury-vapor type rectifier tubes?**

Answer. A choke at the input of a filter cuts down current peaks to safe values which will not damage the filaments of low impedance rectifier tubes of the mercury-vapor type. Incidentally, a choke at the filter input improves regulation because it provides sufficient a-c impedance to limit the peaks caused by the steep wave-front of current, which is characteristic of mercury-vapor tubes.

2.255. *Question.* **Describe the construction and characteristics of a thermocouple type of meter; of a wattmeter.**

Answer. Thermocouple type of meter. A thermocouple consists of two dissimilar metals, such as bismuth, antimony, or constantan brought together under pressure at a junction; the heat generated by a current flowing through the junction will set up an e.m.f. which in turn will cause a direct current to flow to a sensitive d-c milliammeter connected across the junction. Radio-frequency currents can be readily measured in this manner because the r.f. flows only through the junction, not the meter, and the effective alternating current equals the direct current in its heating properties. Thermocouple meters on the whole are sensitive instruments and subject to easy burnout, since the heat generated by the couple increases as the square of the current. In many such instruments the thermocouple is a separate unit connected to the d-c meter and in others the couple is mounted on the back of the d-c meter case in a way that permits the most direct path for the radio frequencies. Although calibration is subject to error on ultrahigh frequencies this does not restrict the use of such meters in general.

Wattmeter. A wattmeter is essentially a combined voltmeter and ammeter used to measure power, and the coils which produce the necessary flux are connected respectively in series and in shunt with the line. The fixed coils are connected in series and the moveable coil, mounted between them and carrying the indicating vane, is connected across the line. Because of their connections with respect to the circuit the fixed coils are called current, or ampere, coils while the moveable one is known as a voltage, or potential, coil. A voltage dropping resistor must be used in series with the potential coil similar to the use of a multiplier in a voltmeter. In a wattmeter the magnitude of the total flux at any moment depends upon the instantaneous values of voltage and current in the line. Hence the power factor of the load is taken care of automatically because the force which acts to turn the moveable coil is proportional to these instantaneous values. This relation permits the scale of the meter to be calibrated directly in watts to read true power, that is, the power being consumed or the energy expended in the circuit at any moment.

2.256. *Question.* **Describe the construction and characteristics of a "D'Arsonval" type meter.**

Answer. The D'Arsonval type meter consists essentially of a permanent magnet, a scale, and a pointer rigidly attached to a moveable coil, the coil being mounted on delicate bearings between the poles of the magnet. Small springs are arranged to pull back the coil and return the pointer, or vane, to zero scale position when no e.m.f. is applied to the coil. This type of instrument operates only on direct current.

The coil rotates when current flows because a force is set up when the flux of the coil tends to displace the flux of the permanent magnet. This action is similar in principle to the rotation of a motor armature when its coils carry current in a magnetic field of constant density. The amount of deflection or movement is directly proportional to the intensity of the current in the coil and proportional to the $\sqrt{R}$, that is, the deflection is proportional to the square root of the power dissipated in the coil. Since the coil rotates in a field of constant density the divisions as marked on the meter scale are uniformly separated.

2.257. *Question.* Describe the construction and characteristics of a repulsion type ammeter.

Answer. The repulsion type ammeter is a moving vane type of meter consisting essentially of a coil and two soft iron pieces disposed in such a manner that they are similarly acted upon by the flux; when current flows the iron pieces repel each other because they are similarly magnetized. One of the soft iron pieces is fixed in position but the other, carrying a pointer, is mounted on a bearing to permit free movement for indicating the amount of repulsion. Since an alternating current changes the polarity of the iron pieces similarly each half cycle the repulsion effect between them continues; hence either a direct current or a current changing in direction will operate the movement. This type of meter has comparatively low sensitivity; a hysteresis loss error is introduced because of the soft iron pieces; it is limited to use at commercial power frequencies.

2.258. *Question.* Describe the construction and characteristics of a dynamometer type indicating instrument.

Answer. A dynamometer type meter does not use a permanent magnet for its stationary field, but instead fixed coils supply the field in which the moveable coil, carrying the indicating vane, is located. The construction is somewhat similar to the wattmeter. In principle this meter depends upon the interaction of two fields, the stationary field being set up by two fixed coils between which is mounted the moveable coil. This type of meter is used only at commercial power frequencies, not for radio frequencies.

2.259. *Question.* Describe the construction and uses of an ampere-hour meter.

Answer. An ampere-hour meter depends for its operation upon the rotation of a nonmagnetic disc, such as a copper or aluminum disc, floating in a pool of mercury to provide electrical continuity, with the disc located in a magnetic field set up by a permanent magnet. When current flows through the disc, eddy currents are set up in it which cause it to rotate one way or the other depending upon the direction of the current flow. The disc is attached to a shaft and through suitable gearing to the indicating pointer which permits the reading of current flow over a period of time, or ampere-hours. Meters of this type are found in battery charging installations, where they indicate the charged and discharged condition of battery banks in ampere-hours capacity. A commercial type ampere-hour meter is provided with an adjustment for making the movement and pointer travel relatively slower on a charging line than on discharge to compensate for losses in the battery.

2.260. *Question.* Describe the construction and characteristics of a hot-wire type indicating instrument.

Answer. The hot-wire ammeter depends for its action on the expansion of a resistance wire when heated by the current being measured, the sag in the wire being carried through a suitable spring and pulley arrangement to the indicating pointer which passes across the calibrated scale. There is a considerable time lag in such a movement owing to the relatively slow heating up and cooling off of the wire; and in addition the kind of alloy wire used readily overheats on slight overloads and if allowed to become red-hot will likely break. Hot wire meters are simple in construction, they do not hold their calibration at varying temperatures, and are subject to a fairly large zero error.

2.261. *Question.* Why is constantan often used in the construction of voltmeter "multiplier" resistors?

Answer. Constantan wire has a zero temperature coefficient, therefore when used for multiplier resistors the temperature error is eliminated, giving the voltmeter a greater percentage of accuracy. The resistance of constantan, an alloy of copper and nickel, remains practically unchanged over a wide range of temperature changes.

2.262. *Question.* A voltmeter is described as having "1,000 ohms per volt." What current is required to produce full-scale deflection?

Answer. A current of 1 milliampere, or 0.001 ampere, will give full-scale deflection.

Calculation: If the voltage at full scale and the total resistance of the meter were given it would be easy to see that by applying Ohm's law formula, $I = E/R$, the current could be found for any given values of E and R. However, when we have only the rating of the meter given in terms of sensitivity, such as *1,000 ohms per volt,* as in this problem, it is still possible to use the same formula and get the same answer by using these given values, 1 volt and 1,000 ohms. The proportionality expressed by Ohm's law explains this clearly. Hence, $I = 1/1{,}000 = 0.001$ ampere.

2.263. *Question.* If two voltmeters are connected in series, how would you be able to determine the total drop across both instruments?

Answer. The total drop across both instruments is the sum of the two meter readings.

2.264. *Question.* What types of meters may be used to measure radio-frequency currents?

Answer. Types of meters used are the thermocouple and the hot-wire types.

2.265. *Question.* If two voltmeters are connected in parallel, how may the total voltage drop across both instruments be determined?

Answer. The same voltage is across each voltmeter when connected in parallel and if the readings are in exact agreement either meter alone would give the actual voltage drop across them. If they do not read alike the average of the two readings could be taken as the total voltage.

2.266. *Question.* How may the current indicating range of a thermocouple be increased?

Answer. The indicating range of the meter attached to a thermocouple may be increased by inserting a voltage dropping resistor in series with the meter connection. Ordinarily, it is not advisable to use resistance shunts, or current transformers at the thermocouple itself to accomplish this purpose, although it may be done. Another method is to connect a low capacitance in series with the thermocouple and then connect this combination across a high capacitance which is in series with the circuit.

2.267. ***Question.*** **Why are copper-oxide rectifiers, associated with d-c voltmeters for the purpose of measuring a.c., not suitable for the measurement of voltages at radio frequencies?**

Answer. A radio-frequency current through a copper-oxide rectifier would cause a large heat loss in such a unit, and voltage readings of reasonable accuracy could not be expected from the rectifier.

2.268. ***Question.*** **If two ammeters are connected in parallel, how may the total current through the two meters be determined?**

Answer. The total current is the sum of the two readings.

2.269. ***Question.*** **Is the angular scale deflection of a repulsion iron vane ammeter proportional to the square or square root of the current, or merely directly proportional to the current?**

Answer. The angular scale deflection of a repulsion iron vane ammeter is proportional to the *square* of the current.

2.270. ***Question.*** **Does an a-c ammeter indicate peak, average, or effective values of current?**

Answer. An a-c ammeter indicates *effective* values of current.

2.271. ***Question.*** **If two ammeters are connected in series, how may the total current through the two meters be determined?**

Answer. The total current is the reading of either meter alone, providing they read alike. If they read slightly different the average of the two could be taken as the total.

2.272. ***Question.*** **Given a milliammeter of full-scale deflection equal to 1 milliampere and an internal resistance of 50 ohms, what value of shunt resistance must be connected across the meter terminals to permit full-scale deflection at a current value of 51 milliamperes?**

Answer. The shunt resistance must be 1 ohm.

Computation: The use of ratio will solve the problem. At the new line current of 51 milliamperes, the shunt will take 50 milliamperes and the meter will still take 1 milliampere, since it is a 1 milliampere movement on full-scale deflection. Comparing the two known current values in relation to the meter's known resistance and the unknown shunt resistance we get

$$\frac{R_{\text{shunt}}}{R_{\text{meter}}} = \frac{I_{\text{meter}}}{I_{\text{shunt}}}$$

Restating the above in terms of the unknown shunt resistance and expressing the current, I, in amperes:

$$R_{\text{shunt}} = \frac{I_{\text{meter}}}{I_{\text{shunt}}} \times R_{\text{meter}} = \frac{0.001}{0.05} \times 50 = 1 \text{ ohm}$$

2.273. ***Question.*** **Given a milliammeter of full-scale deflection equal to 1 milliampere and an internal resistance of 50 ohms, what value of addi-**

tional series resistance must be used to permit operation as a voltmeter with a full-scale deflection at 70 volts?

Answer. The series resistance required to make the milliammeter serve as a voltmeter is 69,950 ohms.

Computation: First find the voltage required to make the meter movement read full scale, thus, $E = I \times R = 0.001 \times 50 = 0.05$ volts. Now, if 70 volts is to be applied across the combined meter and resistance in series, then by subtracting 0.05 volts from 70 volts, we get 69.95 volts, the voltage drop across the resistor itself. Knowing that on full-scale reading the current through the meter and resistor in series will still be 1 milliampere, and having just found the voltage drop across the resistance to be 69.95 volts, the value of the resistance is determined by using $R = E/I$; therefore $R = 69.95/0.001 = 69{,}950$ ohms.

2.274. *Question.* How may a d-c milliammeter, in an emergency, be used to indicate voltage?

Answer. A resistance of suitable value connected in series with the milliammeter would allow it to be used as a voltmeter. However, good judgment would have to be exercised to prevent meter burnout if neither the approximate voltage to be indicated nor the rating of the meter were known. Allowing that the desired full-scale voltage is known and the milliammeter is a standard model whose rating is easily ascertained, then the value of the multiplier resistance, R, could be quickly determined by applying the following formula:

$$R = \frac{E_1 - E_2}{I},$$

where E_1 = full-scale voltage desired,
E_2 = voltage drop in meter for full-scale deflection,
I = current in amperes in meter for full-scale deflection.

2.275. *Question.* What is the purpose of a multiplier resistance used with a voltmeter?

Answer. A multiplier resistance used with a voltmeter permits the indicating range of the meter to be increased.

2.276. *Question.* What are the limitations on the use of copper-oxide rectifiers used with d-c meters?

Answer. The frequency of the alternating current that is to be rectified is the main limitation; the copper-oxide rectifier is used widely on commercial power frequencies, or a low order of frequencies, but serious error in readings would result if used at radio frequencies owing to high temperature developed in the rectifier. Other limitations are the comparatively low current and voltage values that might be handled, although rectifier units are assembled in various series and parallel arrangements to offset this apparent disadvantage, and the copper-oxide rectifier undergoes internal changes inherent in such units over a period of time and service which makes it necessary to recalibrate frequently if accurate readings are desired.

2.277. *Question.* What type of indicating instrument is best suited for use in measuring radio-frequency currents?

Answer. An r-f ammeter of the thermocouple type.

2.278 *Question.* What is the purpose of a "shunt" as used with an ammeter?

Answer. A shunt allows the indicating range of the meter to be increased.

2.279. *Question.* What effects might be caused by a shorted grid condenser in a three-circuit regenerative receiver?

Answer. A shorted condenser would also short the grid-leak and the very principles upon which this type of detector functions would be completely upset; theoretically it would be inoperative because the modulation voltage normally produced across the grid condenser would be lacking and the plate current would contain no audio-frequency component by which the signal could be heard. However, under some conditions of operation it might be possible for the detector to oscillate and act as a beat detector, and if so continuous-wave telegraph signals could be received, although the sensitivity and control of the receiver in general would be greatly impaired.

2.280. *Question.* What would be the effect of a short-circuited coupling condenser in a conventional resistance coupled audio-amplifier?

Answer. A short-circuited coupling condenser would allow positive plate potential to be applied to the control grid of the tube following the coupling condenser. An amplifier control grid with high plate voltage on it would cause excessive grid and plate currents and would result in paralyzing the amplifier; that is, no signal could go through. Furthermore, the tube itself might become damaged or partly so; if the grid and plate elements were allowed to run red-hot too long this might open the grid or introduce gas in the tube, thus making it "soft."

2.281. *Question.* What might be the faults which make a regenerative receiver unable to regenerate or oscillate?

Answer. The most common faults which might make it impossible for a receiver to regenerate or oscillate are as follows:

1. Insufficient coupling between plate and grid, that is, insufficient feed-back.
2. Low operating voltages: Low plate voltage, low filament voltage.
3. Low emission tube.
4. Reversed tickler coil connection.
5. Open-circuit or short-circuit conditions in general, but more specifically troubles due to:
    (*a*) Open pigtail connections at tickler, or tuning elements.
    (*b*) Open grid leak resistance.
    (*c*) Short-circuited grid condenser.
6. Poor circuit connections which might introduce a high resistance to radio frequencies, for example, poorly soldered joints called rosin joints, corroded connections in the wiring, or faulty switch contacts which may be dirty or worn.
7. Reversed plate or filament potentials.

2.282. *Question.* What would be the effect of an open grid-leak resistor in a three-circuit regenerative receiver?

Answer. Failure of the receiver to oscillate or regenerate would result from an open grid-leak resistor under normal conditions. However, a high resistance leakage path between the terminals which hold the grid-leak, such as might result from accumulation of dirt and moisture, would possibly permit reception, but the signal response would be adversely affected.

2.283. *Question.* What might be the cause of low sensitivity of a three-circuit regenerative receiver?

Answer. The principal causes of low sensitivity might be traced to improper value of grid-leak resistance, low filament voltage, and low plate voltage, especially when a "B" battery is used and allowed to become "weak." Another cause might be reversed tickler coil connections, a possibility when circuit rewiring has been done.

2.284. *Question.* **If the plate current of a vacuum tube changed 5 milliamperes for a grid voltage change of 2.5 volts, what is the value of transconductance?**

Answer. 2,000 micromhos.

Calculation: Transconductance, or mutual conductance, is the conductance across the tube from grid to plate. Transconductance, S_m, equals the change in plate current, δI_p, divided by the change in grid voltage, δE_g, or

$$S_m = \frac{\delta I_p}{\delta E_g} = \frac{0.005}{2.5} = 2{,}000 \text{ micromhos}$$

Note. The symbol delta, δ or Δ, is used to denote the amount of change in a value.

2.285. *Question.* **In a self-excited oscillator employing only grid-leak bias, what would result if oscillations cease?**

Answer. The grid would lose its negative bias and allow the plate current to rise excessively, with probable damage to the tube unless overload protection was provided.

2.286. *Question.* **In a shunt-fed plate circuit of a vacuum-tube amplifier, what would result if the plate radio-frequency choke developed a short circuit?**

Answer. The resonant conditions between the grid and plate tanks would be greatly upset because of the change in plate impedance, and as a result the d-c plate current would rise and normal r-f output could not be expected. A short-circuited r-f plate choke would place an additional impedance, the resistance of the d-c plate power supply, in shunt with the plate r-f tank from plate to ground and in effect is like short-circuiting the output so far as r.f. is concerned.

2.287. *Question.* **In a series-fed plate circuit of a vacuum-tube amplifier, what would result if the plate supply bypass condenser developed a short circuit?**

Answer. A short-circuited bypass condenser would also cause the plate d-c power supply to be short-circuited since the positive d-c line would be grounded. If this happened the amplifier not only would be inoperative but serious damage to the power supply might result if overload protection were not provided.

2.288. *Question.* **In a shunt-fed plate circuit of a vacuum-tube amplifier, what would result if the plate radio-frequency choke developed an open circuit?**

Answer. Plate voltage would be removed from the tube, making it inoperative.

2.289. *Question.* **In a shunt-fed plate circuit of a vacuum-tube amplifier, what would result if the plate blocking condenser developed a short-circuit?**

Answer. A short-circuited plate blocking condenser would cause the plate d-c power supply also to be short-circuited through the low d-c resistance path furnished by the plate tank coil; in other words, the plate positive high voltage would be grounded. This trouble would result in damage to the plate power supply if plate overload protection were not provided.

2.290. *Question.* **What is the effect of local action in a lead-acid storage cell and how may it be compensated?**

Answer. Local action causes a slow forming of sulphation on the plates, the effect of a very gradual discharging of the cell, which in time will decrease the ampere-hour capacity of the cell.

Local action may be compensated by keeping the cell in good condition, by maintaining correct charge and discharge rates, and by keeping the cell on trickle charge when not in active use.

2.291. *Question.* **Why should adequate ventilation be provided in the room housing a large group of storage cells?**

Answer. A room where a large bank of batteries is being charged should be adequately ventilated for the following reasons: To protect the personnel from the obnoxious fumes, to keep the batteries from overheating, and to prevent accumulation of explosive hydrogen gas around the cells.

2.292. *Question.* **When should distilled water be added to a lead-acid storage cell and for what purpose?**

Answer. It is best to add distilled water to a cell before charging it, but in any event, distilled water should be added if the plates become exposed to the air through improper attention to the battery. The purpose of adding the water is to keep the plates covered and to replace the water lost through evaporation. In the chemical reactions of a lead-acid cell the sulphuric acid in the solution does not evaporate, only the water.

2.293. *Question.* **How may the polarity of the charging source to be used with a storage battery be determined?**

Answer. Several methods are suggested here for determining the polarity of a d-c charging source.

Voltmeter Method. It is usual practice for the manufacturer to mark a + sign on or close to one of the terminal posts of a d-c voltmeter; the positive side of the line when connected to this post will make the indicating pointer read up, or in the correct direction on the scale.

Salt Water Method. Dip the positive and negative wires in a glass of water to which salt has been added and carefully hold them about an inch apart; the negative wire is the one on which the greater quantity of bubbles is formed.

Potato Method. By inserting the bare ends of the positive and negative wires into a raw potato, in a place where the skin has been cut away, and holding them a safe distance apart, an inch or so, it will be noticed soon that the potato turns bluish green in color around one of the wires; this is the positive wire and the discoloration is caused by decomposition of the starchy substance.

Litmus Paper. Placing the positive and negative wires about a quarter of an inch apart on a piece of wet litmus paper will cause a red mark to appear where the positive wire is held.

Note. Extreme caution should be used when making tests suggested where open leads are used with power on. Do not come into contact with the bare ends of the wires nor allow them to touch each other. A safer method is to insert a load in series with one side of the line, by using a lamp, for example, so that if the ends do accidentally touch, a short circuit will be prevented.

2.294. *Question.* **Describe the care which should be given to a group of storage cells to maintain them in good operating condition.**

Answer. The various items relating to the proper care and maintenance of storage batteries are as follows:

(*a*) Maintain electrolyte at the proper level in each cell. Keep the level about one-half inch above the plates by adding distilled water, or approved pure water, from time to time as required, but avoid overfilling to a point where the electrolyte is likely to well out through the vent during the gassing period on charge.

(*b*) Keep tops of cells clean and dry to prevent creepage.

(*c*) Be sure all terminal connections and lugs are tight to ensure good electrical contact and to reduce the possibility of sparking.

(*d*) Keep terminal lugs and posts free from corrosion. These can be covered with a thin layer of vaseline or a nonmineral grease.

(*e*) Do not overcharge the battery frequently; about once a month is permissible.

(*f*) Do not overdischarge the battery.

(*g*) Do not charge too rapidly or at too high a rate. Charge at rates recommended by the manufacturer of the battery.

(*h*) Keep the charging polarity correct with respect to the battery. This should be carefully watched to be certain the positive and negative sides of the charging line, respectively, connect to the positive and negative terminals of the battery.

(*i*) Before placing batteries on charge observe that the voltage of the charging line is above the battery voltage.

(*j*) Do not allow batteries to stand too long in a discharged condition. Recharge as soon as practicable after discharge.

(*k*) Take specific gravity readings as frequently as required to keep a close check on battery conditions of charge and discharge; a hydrometer is necessary only in the case of the lead-acid type. An Edison cell is checked with a voltmeter.

(*l*) Avoid high temperatures in the cells. Keep cell temperatures preferably at an average of not over 80° to 90° F. and not over a temperature of 100° to 115° F. as a maximum.

(*m*) Provide adequate ventilation in the room where batteries are charged.

(*n*) Never add acid to lead-acid cells except to replace electrolyte known to have been lost through spilling and only in such cases where the normal specific gravity after charging does not come up to normal. If acid must be replaced add it to the solution before a charging period.

(*o*) Never bring an exposed flame or cause an electric spark near cells during the charging period. All storage cells when charging give off **hydrogen,** which is an **explosive gas.**

(*p*) Do not allow salt or salt water or any foreign matter to find its way into a cell.

(*q*) When cells are not in active service keep them floating on a trickle charge.

(*r*) Do not always use the same cell as the "pilot cell" in a lead battery for taking gravity readings. A very small amount of electrolyte is lost to a cell each time a hydrometer reading is taken, and if readings are taken daily this condition can be equalized by using a different cell every few weeks for the pilot cell.

(*s*) Electrolyte in an Edison cell should be replaced when it becomes aged.

(*t*) Where batteries are exposed to low temperatures keep them properly charged to prevent freezing; the operator should consult a chart giving low temperatures and corresponding specific gravities at which the electrolyte will freeze.

2.295. ***Question.*** **What may cause the plates of a lead-acid storage cell to buckle?**

Answer. Overdischarge or overheating may cause buckling of plates in a lead-acid cell. Inadequate ventilation or attempted charging with incorrect polarity, if continued too long, will raise the temperature.

2.296. ***Question.*** **What may cause "sulphation" of a lead-acid storage cell?**

Answer. The term "sulphate" is used to apply to a dense kind of sulphate which builds up on the plates from allowing a battery to stand for a long period of time in a discharged condition, or by repeatedly carrying the discharge considerably beyond the limit recommended by the manufacturer, or by persistently failing to bring the battery to a fully charged condition after each discharge.

2.297. ***Question.*** **What chemical may be used to neutralize a storage cell acid electrolyte?**

Answer. Ammonia or sodium bicarbonate (baking soda) are two neutralizing agents.

2.298. ***Question.*** **What steps may be taken to prevent corrosion of lead-acid storage cell terminals?**

Answer. Clean the terminals thoroughly with an alkaline solution and after drying cover them with a thin layer of vaseline, or noncorrosive grease.

2.299. ***Question.*** **Why are bypass condensers often connected across the brushes of a high-voltage d-c generator?**

Answer. The use of bypass condensers across brushes of high-voltage d-c generators is a protective measure; usually generators of this type supply plate potential to high power stages and in the event of a high-frequency voltage surge, or r-f kick-back, the generator armature might be damaged if this bypass of low reactance were not in the circuit. In practice two condensers in series are generally connected across the brushes with the common leg between them going to ground. Condensers connected across the brushes also serve as a filter.

2.300. ***Question.*** **What materials and technique should be used to keep the commutator of a d-c motor or generator clean?**

Answer. A very fine grade of sandpaper, for example No. 0000, should be used to clean a commutator; take a strip of the sandpaper wrapped partly around a wooden block and gently hold the sanded side against the surface of the commutator while it is running; finish by carefully removing all grit and particles due to sanding from around the brushes and the commutator after stopping the machine; a final polishing may be given with the machine running by holding a pad made of heavy duck, or canvas, against the commutator. Extreme caution must be exercised by the operator when working around rotating machinery and especially high-voltage generators.

Note. Emery cloth or abrasive materials must **never** be used on commutators because it scores or cuts the copper, and the fine emery particles lodging between segments short-circuit them.

2.301. ***Question.*** **What may cause a motor-generator bearing to overheat?**

Answer. Some of the causes of overheating which are common to both a motor and a generator are as follows: Excessive load, lack of lubrication, bearings too tight, severe sparking at the commutator, insufficient armature end-play, improper armature alignment.

2.302. ***Question.*** **How may the radio-frequency interference, often caused by sparking at the brushes of a high-voltage generator be minimized?**

Answer. The sparking which causes radio-frequency interference may be minimized by installing a suitable ripple filter, or a radio-frequency filter, or both at the output of the generator. The filters consist of chokes and condensers for by-passing; in ripple filters the L and C values required are much higher than in filters designed for r-f suppression.

2.303. ***Question.*** **What may be the effect of shifting the brushes of a d-c generator from the "neutral position"?**

Answer. Shifting of the brushes from their neutral position will cause serious sparking. In addition, the terminal voltage will be lowered, but this effect is of secondary importance in any case where sparking occurs; sparking, if continued very long, would cause serious damage to the commutator.

2.304. ***Question.*** **Describe the treatment which would be given an overheated motor-generator bearing.**

Answer. If a hot bearing should develop make every effort to keep the armature running but reduce the speed and remove the load if possible. The machine must **never** be stopped suddenly, which might cause the bearing and shaft to "freeze," that is, these parts would lock together almost like one piece and the armature and bearing would have to be completely disassembled to effect repairs. The rule is to keep the armature rotating at the slowest speed possible without load and treat the bearing by supplying liberal quantities of lubricating oil and graphite to the bearing, or direct the cooling draft of an electric fan on the bearing, or apply cloths or towels soaked in ice water against the bearing journals, being careful that excitation is removed in the case of a high-voltage generator. If the room ventilation is poor then open any doors or windows. After the bearing cools off the oil wells should be flushed out and refilled with fresh lubricant of the proper grade.

2.305. ***Question.*** **What may cause a generator to fail to "build-up"?**

Answer. In a self-excited generator the loss of residual magnetism would be the most likely cause for failure to build up voltage. Other possible causes common to both self-excited and separately excited generators are an open field, or brush not making contact with the commutator or rings, or broken pigtail connection to a brush.

2.306. ***Question.*** **For what purposes may a "reverse current" relay be used?**

Answer. A "reverse current" relay finds application in storage battery charging equipment to prevent batteries from discharging into the source if the charging voltage became subnormal and dropped below the battery voltage; another use is in rectifiers, especially where mercury-vapor tubes are employed, to protect them from flash-back which reverses the current flow through the tubes; still another use is in selective switching to perform the necessary functions.

2.307. *Question.* **Explain the difference in construction and operating characteristics of high- and low-voltage fuses.**

Answer. A high-voltage fuse requires a comparatively long cartridge in which the fuse wire is located to provide a wide breaking distance, or long path, between the metal end terminals; the fuse wire is attached to these metal ends which also serve for mounting the fuse in clips. The fuse wire is relatively small for high-voltage applications where the currents generally are of a lower order than in low-voltage circuits. Low-voltage fuses require only a comparatively small cartridge or plug with a short breaking distance, or short path for the current in the fuse wire. Fuses in the high-voltage classification are generally for voltages above 750.

2.308. *Question.* **Explain the uses and limitations of fuses and circuit breakers as used in radio equipment.**

Answer. Fuses and circuit breakers are both protective devices, but a fuse when blown destroys itself and must be replaced, whereas a circuit breaker can be quickly reset for further use. Usually a circuit breaker is made so that it can be adjusted to trip at some specified value of overload current. Some types are made to remain closed on normal load and open on no-load, or on underload conditions. Another application is where a circuit breaker functions to trip open a power line owing to loss of line voltage and when the voltage comes on again it could not unexpectedly start up equipment that was previously operating but stopped for lack of line voltage. A fuse has only one use and a fixed rating. The initial cost of a circuit breaker is very high compared with that of a fuse with its mounting, a fact which sometimes limits the use of circuit breakers.

2.309. *Question.* **What is meant by a "polarized relay"?**

Answer. A "polarized relay" is a relay that requires connection to a direct-current circuit according to its polarity signs because it functions on a predetermined direction of current flow.

2.310. *Question.* **Why are high reactance head telephones generally more satisfactory for use with radio receivers than low reactance types?**

Answer. A head telephone set is generally connected directly in the plate circuit of a vacuum tube, hence the high reactance type would prove more satisfactory because its impedance comes much nearer to matching the plate resistance of a vacuum tube than the low reactance type. It is known that for best performance the impedance of the load in the plate circuit should be about twice the plate resistance of the tube. However, low reactance head telephones could be used with a radio receiver providing they were coupled into the plate circuit through a matching transformer.

2.311. *Question.* **What may cause packing of the carbon granules in a carbon button microphone?**

Answer. Packing may be caused by excessive button current or by careless handling which would result in sudden jolts or jarring while the current is flowing.

The granules may pack almost instantly in extreme cases, or they may pack in time under some conditions of regular service. In general, excessive mechanical pressure between points of contact in the carbon cup causes the granules to pack.

2.312. ***Question.*** **Why should polarity be observed in connecting head telephones directly in the plate circuit of a vacuum tube?**

Answer. Higher sensitivity results when the proper polarity is observed. The greatest deflection of the diaphragms for a given signal current is possible only when the direct current flowing through the small coils is in the direction to produce flux which aids the flux of the permanent magnets. Incidentally, when the flux set up by the small coils, or bobbins, is of proper polarity it assists in keeping the permanent magnets magnetized.

Note. If head telephone cords are not color coded the proper polarity can be readily determined by alternately reversing the phone cord tips across a low voltage d-c source; the proper connection will give the louder click.

2.313. ***Question.*** **What precautions should be observed in the use of a double-button carbon microphone?**

Answer. Several precautions should be observed in the use of a double-button carbon microphone, namely, the current in each button should be the same, the microphone should be mounted in a vertical position, and when current is flowing it should not be handled roughly or subjected to vibration or sound intensities that might cause blasting.

2.314. ***Question.*** **If low impedance head telephones of the order of 75 ohms are to be connected to the output of a vacuum-tube amplifier, how may this be done to permit most satisfactory operation?**

Answer. A low impedance head telephone set can be used satisfactorily by coupling it to the tube's output through an impedance matching transformer.

Discussion. The turns ratio of the matching transformer is found by taking the square root of the impedance ratio, and to find the impedance ratio the plate resistance of the tube (not given in the statement of the question) is divided by the load impedance, or 75 in this case.

2.315. ***Question.*** **What is the effect on the resonant frequency of adding an inductor in series with an antenna?**

Answer. The resonant frequency of the antenna is decreased. This is because the inductor connected in series increases the inductance of the antenna circuit. In terms of wavelength, the antenna resonates at a longer wavelength when its inductance is increased.

2.316. ***Question.*** **What is the effect on the resonant frequency of adding a capacitor in series with an antenna?**

Answer. The resonant frequency is increased by the addition of a capacitor in series with an antenna. A series capacitor lowers the electrical length of an antenna and therefore it makes the wavelength shorter and the frequency higher.

2.317. ***Question.*** **Which type of antenna (Hertz, Marconi, Inverted L, etc.) has the greatest physical length for a given resonant frequency?**

Answer. The Hertz antenna has the greatest physical length for a given resonant frequency.

2.318. ***Question.*** **What is the velocity of propagation of radio-frequency waves in space?**

Answer. The velocity of a radio wave in space is 300,000,000 meters per second, as generally accepted.

2.319. ***Question.*** **What is the relationship between the electrical and physical length of a Hertzian antenna?**

Answer. The physical length is approximately 95 per cent of the electrical length owing to capacitance to ground and end effect. In terms of wavelength the radiated wave equals approximately twice the physical length measured in meters.

2.320. ***Question.*** **If you desire to operate on a frequency lower than the resonant frequency of an available Marconi antenna, how may this be accomplished?**

Answer. A lower resonant frequency is obtained by adding an inductor in series with the antenna. In terms of wavelength, a longer wavelength is obtained when a series connected inductor is added because this increases the inductance of the antenna.

2.321. ***Question.*** **What will be the effect upon the resonant frequency if the physical length of a Hertzian antenna is reduced?**

Answer. Shortening a Hertz antenna makes it resonant at a higher frequency, that is, at a shorter wavelength.

2.322. ***Question.*** **If the thermocouple of your radiation ammeter burned out and no spare was available, what would you substitute for it, or what methods could be used to determine that the antenna circuit of your transmitter was adjusted to resonance?**

Answer. One method for determining resonance of an antenna without an antenna ammeter is to use a pick-up loop consisting of a wire several inches in diameter to which is attached a visual indicator, such as a flashlight bulb; the loop should be loosely coupled to the antenna inductor and at resonance the indicator will show maximum brilliancy. Another method is to use a 110-volt lamp of suitable wattage as determined by the approximate amount of power to be dissipated in the lamp; if necessary two or more lamps in parallel could be used, with the lamp bank resistance connected temporarily in series with the antenna; the lamps burn brightest at resonance. Again, a plate milliammeter in the final stage could be used to check for resonance; at resonance the antenna takes the greatest amount of power from the final stage and this causes its plate current to read maximum; at points off resonance the plate current reads lower. Other methods possible are by the use of a wavemeter or frequency meter equipped with an indicator, such as a neon bulb, flashlight bulb, or r-f meter, and by the use of a crystal rectifier and a d-c milliammeter in conjunction with a tuned r-f circuit.

2.323. ***Question.*** **Which type of antenna has a minimum of directional characteristics in a horizontal plane?**

Answer. The vertical type antenna.

2.324. ***Question.*** **What factors determine the resonant frequency of any particular antenna?**

Answer. The factors which determine the resonant frequency of a particular antenna are its physical length, whether it is grounded or ungrounded, and the effect on it caused by surrounding objects.

2.325. *Question.* **If the resistance and the current at the base of a Marconi antenna are known, what formula could be used to determine the power in the antenna?**

Answer. $P = I^2R$.

Note. The radiation resistance, R, must be measured at the same point in the antenna as the current, I.

2.326. *Question.* **Does the resistance of a copper conductor vary with variations in temperature and if so, in what manner?**

Answer. The resistance of copper does vary with changes in temperature; its resistance increases with temperature.

2.327. *Question.* **What material is best suited for use as an antenna strain insulator which is exposed to the elements?**

Answer. An insulator material best suited to withstand the weather is glazed porcelain.

2.328. *Question.* **What material is frequently used for relay contacts? Why?**

Answer. A material in wide use for relay contacts is *silver* because it has high conductivity and good contact properties; for example, it does not pit easily, atmospheric gases have negligible effect on it, and its cost is relatively low.

2.329. *Question.* **Describe the operation of a crystal detector (rectifier).**

Answer. A crystal has natural properties which allows it to pass a considerably larger current in one direction than in the other; it is a partial rectifier. Therefore, if an a-c voltage is applied to the crystal it causes current pulses of large amplitude to flow on alternate half cycles whereas the alternations in the opposite direction will be almost blocked. When used as a detector of radio signals the crystal is connected in series with high impedance headphones across which is shunted a condenser, and this arrangement in turn is connected across a tuned r-f circuit. The principle of operation is as follows: An incoming signal which is modulated, or contains an audio-frequency component, will send large current impulses of varying amplitude through the crystal on alternate half cycles that charge the condenser, and therefore the voltage across the condenser will vary according to the *average* of all the amplitudes. This *average* voltage change represents the *audio-frequency component.* Thus, the voltage appearing across the condenser follows the modulation envelope, or audio waveform. The condenser being in shunt with a high impedance, the headphones will discharge, sending an audio-frequency current through the phones to actuate the diaphragms and make the signal audible. A crystal detector will respond only to radio signals having a modulation envelope, that is, voice modulated, or to type A-2 emission whose signals have a tone frequency. Signals of the continuous-wave type cannot be received because they would give a steady average voltage across the condenser resulting in a steady, or unvarying, current in the headphones.

2.330. *Question.* **Define a "damped wave."**

Answer. A "damped wave" is a train of oscillations in which the amplitude of each succeeding alternation decreases in some regular order until the wave dies out, or "damps" out. In a circuit of relatively high resistance the amplitudes decrease at a fast rate resulting in only a comparatively few oscillations before they cease. On the other hand, the oscillations continue longer before they stop if the circuit resistance is low.

2.331. *Question.* Why is rosin used as soldering flux in radio construction work?

Answer. Rosin makes the best soldering flux because it is noncorrosive; and having excellent insulating qualities, the flux will not cause short-circuit troubles in places where it may happen to flow and remain after soldering.

2.332. *Question.* What is meant by a "harmonic"?

Answer. A "harmonic" is a component which is an integral multiple of the fundamental frequency.

2.333. *Question.* What is the function of a "no-voltage release" often incorporated in a d-c motor starter?

Answer. A "no-voltage release" places the starter in the "off" position should the line voltage fail, or in some types if the motor field opens, which makes it impossible for the motor to start up unexpectedly when voltage comes on again without making use of the starter and its resistance in the usual way. This feature protects both the line and motor against damage which might prove serious in some installations if full line voltage were suddenly applied to a motor without the starting resistance being in the circuit.

2.334. *Question.* Explain what technique you would employ in giving assistance to a person who was in contact with high voltage.

Answer. After removing the victim from contact with the high voltage by any means which protects the person giving assistance from possible shock, then some kind of artificial respiration should be started without delay. The **prone pressure method** is explained, with precautions to be observed as follows:

PRONE PRESSURE METHOD

First Things To Do and Precautions. Open the supply switch, but, if this cannot be done without delay, proceed at once to free the victim from contact with the high voltage.

Do not touch the victim with your hands or any part of your body.

Keep a safe distance while forcibly pulling the victim from the charged conductor, using for the purpose any article that is dry and a nonconductor, such as a length of rope, a stick or pole, or clothes.

Next loosen clothing at the neck and chest and lay the victim in a prone position, extending one arm out straight; bend the other arm at the elbow and rest the head on it with the head turned to one side to permit free use of the nose and mouth.

Begin applying artificial respiration immediately, and continue for 4 hours, if necessary, or until the shock has been pronounced fatal by a doctor.

Summon a doctor, or pulmotor service, through any person who may be present, but do not stop resuscitation operations for this purpose. If others are present they can give proper treatment for any serious burns.

Purpose of the Prone Pressure Method. The purpose in general is to apply your weight to the victim's chest in a manner that will force air out of the lungs and by removing the pressure the lungs will expand and draw in air; a cycle or beat of artificial respiration should be timed to give about 15 beats per minute, that is, to approximate closely a rhythm corresponding to natural respiration.

Technique Used in Prone Pressure Method. Straddle victim's back; kneel down with your knees opposite the victim's thighs.

Applying your weight: Bend over with arms held straight, do not bend elbows, and place the palms of hands against victim at the small of the back; with a straight arm motion apply your weight gradually while slowly counting to yourself to keep a certain rhythm for this downward motion. Do not use the arm muscles.

Removing your weight: Straighten up and remove the pressure; count and keep the same rhythm on this upward motion.

Continue this operation, which consists essentially of bending over to apply pressure and leaning back to remove it; you will appear to be swinging back and forth in slow rhythm to simulate periods of natural respiration.

Proper position of hands to apply pressure: Spread thumb from the palm with fingers held straight out and with your small finger placed just at the lower rib; rest the palm against the small of the back, and the hand when held in a natural position will cause the fingers to bend around the side with the finger tips pointing down.

How to relax: On the upward movement when pressure is removed, that is, while straightening up to remove your weight, bring the hands over and rest them momentarily on your knees and at the same time relax the arm and body muscles and then resume the downward movement. Remember that the more completely you relax for this brief interval the longer you can continue operations without fatigue. However, if relief is necessary, or if several persons work in a relay each one can shift over quickly without breaking the rhythm.

How to prevent off-balance strain: Kneeling down and swinging your body back and forth as is necessary may tend to throw you off balance, particularly at the moment when the downward stroke is completed; to avoid this strain adjust yourself over the victim's body so that your shoulders are directly above your wrists at the end of the downward, or pressure, stroke.

Important Remarks. Do not leave off the operation of artificial respiration after once started unless, of course, unusual circumstances require it, or as previously suggested.

If the victim must be moved to another place do it in some way that will permit continuation of the operation.

Anything in the victim's mouth, such as false teeth, chewing gum, and the like, should be removed as soon as possible but without interrupting the operation.

If the victim shows signs of breathing do not stop resuscitation at once but keep on until breathing is strong or the individual is revived.

Stimulants, such as a spoonful of aromatic spirits of ammonia, or coffee, or tea, should be given but only when the victim is conscious.

After breathing is restored keep the unfortunate individual warm and lying quiet until fully revived.

2.335. *Question.* What is the function and purpose(s) of interlock relay switches which are often provided on the access doors of modern radio transmitters?

Answer. Interlock relay switches on access doors are provided as a protection to the personnel because they remove high voltage from the circuits immediately upon opening a door.

2.336. *Question.* How may a transmitter or receiver be protected against damage due to high values of induced atmospheric electricity collected by an antenna system?

Answer. A safety gap consisting of two electrodes connected respectively across antenna and ground posts of the equipment will afford protection. In high power transmitter antenna systems this takes the form of a horn-type gap in which the electrodes are especially shaped to allow a surge to travel to the open ends and break. All commercial receivers for marine services are equipped with a safety gap in which the electrodes are separated about the thickness of a calling card. The term "lightning arrester" is usually applied to such devices which have the property of reducing the voltage of a surge acting across its terminals and restoring itself to normal after the follow current, if present, is interrupted. A transmitter or receiver antenna may also be provided with a high resistance between antenna and ground posts to allow static charges to drain off.

2.337. *Question.* Why should all exposed metal parts of a transmitter be grounded?

Answer. Grounding of exposed metal parts protects the personnel against possible shock which might happen if these parts were above ground potential; ungrounded metal parts which are likely to be touched present a hazard, dangerous to life, in high-power installations. Grounding eliminates electric fields and possible coupling effects between equipment.

ELEMENT 3

RADIOTELEPHONE

3.1. *Question.* In the diagram given in Figure 43:

(*a*) Knowing the impressed voltage E and the values of the resistors R_1, R_2, and R_3, explain how you would calculate the current in each of the resistors.

(*b*) Knowing the value of the current in R_1 and the values of the resistors R_1, R_2, and R_3, how would you calculate the currents in R_2 and R_3? How would you calculate the voltage drop across each of the resistors?

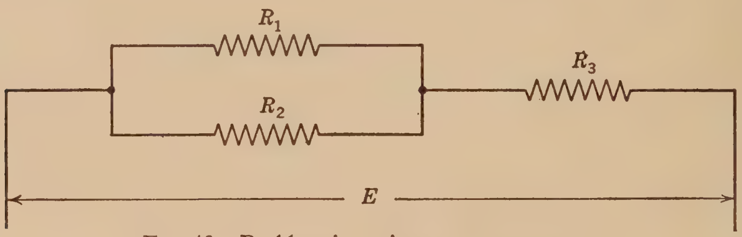


FIG. 43. Problem in resistance measurement.

Answer. (*a*) First determine the total resistance of the circuit. This is done by finding the resistance of the parallel branch R_1 and R_2, to which is added R_3, in series. Then apply Ohm's law, $I = E \div R$, to determine the total current. The total current flows through R_3 and divides proportionally in R_1 and R_2, according to their respective values. Next find the voltage drop across R_3, so that this value may be subtracted from the known impressed voltage E to give the voltage drop across R_1 and R_2 in parallel. Since the voltage drop across either R_1 or R_2 is the same, and being given the value of each resistor, the current through them can be found by using $I = E \div R$. Or, the step just given could be worked out instead by finding the current in R_1 by Ohm's law, and then subtract this value from the total current to find the current in R_2. Another method which makes it unnecessary to find the voltage drop across R_1 and R_2, the parallel branch, is to use ratio to calculate the current in each resistor, since their values are given and the total current taken by them has been calculated.

Calculation: The foregoing explanation for calculating the current in each resistor is worked out in steps with the necessary formulas.

Step 1. To find total resistance, R_{total}:

$$R_{\text{total}} = \frac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2}} + R_3$$

Step 2. To find current through R_3, which is the total current: $I_3 = \frac{E}{R_{\text{total}}}$

Step 3. To find voltage drop across R_3: $E_3 = I_3 \times R_3$

Step 4. To find voltage drop across R_1 or R_2, the same value for either: $E_1 = E_{\text{applied}} - E_3$

Step 5. To find current through R_1: $I_1 = \frac{E_1}{R_1}$

Step 6. To find current through R_2: $I_2 = I_{\text{total}} - I_1$

Note. The current in R_1 can be determined without using the voltage drop method (step 4) followed by Ohm's law (step 5) to find current. To figure the current in R_1 by the use of ratio omit step 4 above and work out step 5 as follows:

Step 5. To find current, I_1, through R_1: $I_1 = I_{\text{total}} \left(\frac{R_2}{R_1 + R_2} \right)$

Step 6. Repeat, same as Step 6 above to find current, I_2, through resistor R_2.

(*b*) **Part 1. How to calculate the currents in R_2 and R_3.**

Since the current through R_1 and the values of resistors R_1 and R_2 are known, the current, I_2, in resistor R_2 is found by using ratio, thus

$$\frac{I_2}{I_1} = \frac{R_1}{R_2}, \quad \text{or} \quad I_2 = I_1 \times \frac{R_1}{R_2}$$

Since R_3 is in series with the circuit the current through R_3 is the sum of the currents in R_1 and R_2, because the latter are in parallel; therefore

$$I_3 = I_1 + I_2$$

Part 2. How to calculate the voltage drops across each resistor.

Since the value of each resistor and the current through them is known, the voltage drop across each resistor is found by applying Ohm's law, similarly for each case, where $E = I \times R$. Hence

$E_1 = I_1 \times R_1$, or voltage drop across resistor R_1

$E_2 = I_2 \times R_2$, or voltage drop across resistor R_2

$E_3 = I_3 \times R_3$, or voltage drop across resistor R_3

3.2. *Question.* In the diagram given in Figure 44 compute the following voltages: d-c plate voltage, d-c grid bias voltage, and d-c supply voltage.

Answer. The d-c plate voltage is 75 volts, the d-c grid bias is 7.5 volts, and the supply voltage is 82.5 volts.

Computation:

(1) **To find plate voltage.** The voltage drop across the 15,000-ohm resistor is the plate voltage, since this resistor is connected between cathode and plate. Find the current through the 15,000-ohm resistor from the given values in the diagram. From the circuit we see that the current through the 15,000 ohms is the difference between the total current, 0.030 ampere, and the current drawn by the plate, 0.025; therefore, $0.030 - 0.025 = 0.005$ ampere, the current through the 15,000 ohms. The voltage drop across this resistor, applying $E = I \times R$, is $0.005 \times 15{,}000$, which equals 75 volts, or the plate voltage.

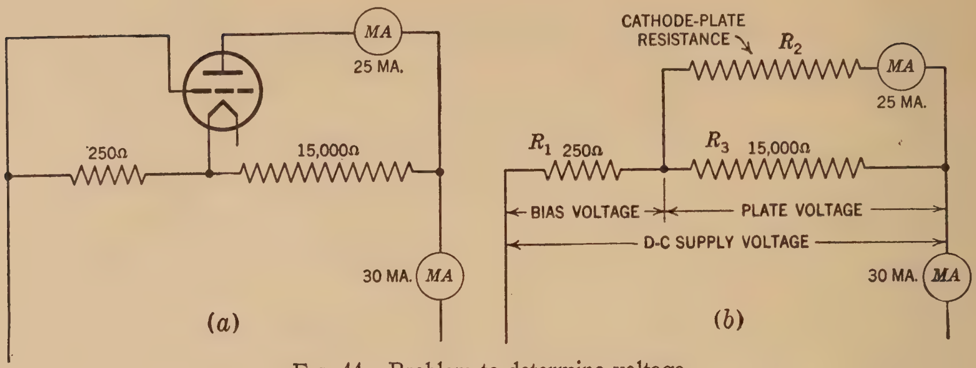


FIG. 44. Problem to determine voltage.

(2) **To find grid bias voltage.** The total current, 0.030 ampere, flows through the bias resistor, 250 ohms, because it is in series with the circuit up to the cathode, but from this point the total current divides, part going through the plate circuit in the tube and the rest through the 15,000 ohms. Therefore, again applying Ohm's law, $E = I \times R$, we find the voltage drop across the 250 ohms to be 0.030 × 250, or 7.5 volts, the bias voltage.

(3) **To find the supply voltage.** The total voltage impressed on the circuit is the sum of the voltage drop across the bias resistor and the voltage drop across the parallel branch consisting of the plate in one leg and the 15,000 ohms in the other. Therefore, $7.5 + 75 = 82.5$ volts, the supply voltage.

3.3. *Question.* Define a negatively charged body. A positively charged body.

Answer. A negatively charged body is one having an excess of free electrons, or in other words, a deficiency of positive protons. Hence, electrons leak off or leave a negatively charged body when the body is neutralized. On the other hand, a positively charged body has a deficiency of free electrons so that electrons are taken on or flow into the body to neutralize it.

3.4. *Question.* What are the desirable electrical characteristics of a radio-frequency choke coil?

Answer. A radio-frequency choke coil should have low distributed capacity, low resistance, and an inductance value that will make its resonant frequency considerably higher than the frequency to be suppressed. If a choke has a resonant frequency lower than the frequency to be filtered its distributed capacitance becomes more effective in bypassing and the coil becomes less efficient as a choke. It is also important for a choke to have the proper current-carrying capacity for the circuit in which it is intended to be used.

3.5. *Question.* Explain the purposes and methods of neutralization in radio-frequency amplifiers.

Answer. The purpose of neutralization of an r-f amplifier is to prevent the amplifier from going into self-oscillation, that is, to prevent its generating a frequency in its output different from the frequency at which it is being driven.

The methods of neutralization fall into the following classes, namely, (1) where the neutralizing voltage is taken from some part of the tube's output and fed back to the grid at a potential equal and opposite in phase to a potential on the grid that would cause oscillation, and (2) where feedback energy is taken from some portion of the grid circuit, or input, and returned to the plate.

3.6. *Question.* **In a circuit consisting of an inductance having a reactance value of 100 ohms and a resistance of 100 ohms, what will be the phase angle of the current with reference to the voltage?**

Answer. The phase angle will be 45°.

Discussion. See Figure 45. Current in a series circuit containing resistance, R, and inductive reactance, X, lags the voltage by an angle given by:

$$\theta = \tan^{-1}\frac{X}{R}$$

$$\theta = \tan^{-1}\frac{IX}{IR} = \tan^{-1}\frac{X}{R}$$

Therefore, in the given problem we have

$$\theta = \tan^{-1}\frac{100}{100} = 45°. \quad \textit{Ans.}$$

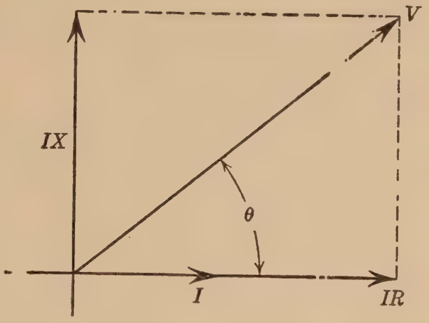


FIG. 45. Problem in a-c circuit theory.

3.7. *Question.* **In a circuit consisting of a capacitance having a reactance value of 100 ohms, what will be the phase angle of the current with respect to the voltage?**

Answer. The current will lead the voltage by 90°.

Discussion. For circuits containing capacitive reactance, as in this case, the angle is 90° lead regardless of the value of the reactance and in the absence of resistance. Circuits containing only pure reactance show a 90° lag or lead of current with respect to voltage.

3.8. *Question.* **What is the effective value of a sine wave in relation to its peak value?**

Answer. Effective value = 0.707 × peak value.

3.9. *Question.* **What is the meaning of "phase difference"?**

Answer. In an electrical circuit "phase difference" means that the voltage and current do not reach maximum and minimum values at the same instant, or comparing the events over a full cycle of current and voltage, a difference in phase means that certain points on a current wave compared relatively to similar points on a voltage wave are occurring either ahead or behind each other and not at the same instant; this difference is measured in electrical degrees. See answer to Question 5.21.

3.10. *Question.* **What factors must be known in order to determine the power factor of an alternating-current circuit?**

Answer. The factors necessary to know are the resistance and the reactance.

Discussion. The power factor could be determined by knowing the resistance and the impedance, since p.f. = R/Z.

A practical way to find the power factor is to take readings on a voltmeter, ammeter, and wattmeter connected in the circuit and apply the formula p.f. = W/EI.

3.11. *Question.* **What is the product of the readings of a voltmeter and ammeter in an alternating-current circuit?**

Answer. The product of a voltmeter and ammeter reading in an alternating-current circuit gives the *apparent* power, known as "volt-amperes."

3.12. *Question.* In what units is the power output of an alternator (a-c generator) usually expressed?

Answer. The power output of large alternators is rated in volt-amperes, or kilovolt-amperes. These become watt and kilowatt ratings respectively when the power factor is unity. The watt is used for small a-c machines.

3.13. *Question.* What are the properties of a series condenser acting alone in an a-c circuit?

Answer. A current will flow which leads the voltage by 90°, and the power taken from the line will be negligible if the condenser has a high Q value.

3.14. *Question.* If the value of inductance in a purely inductive circuit is doubled, what is the effect on the phase angle?

Answer. Doubling the inductance in a purely inductive circuit has no effect on the phase angle. Regardless of the value of the inductance, the current lags the voltage by 90°, and therefore is wattless.

3.15. *Question.* What is the reactance value of a condenser of 0.005 microfarad at a frequency of 1,000 kilocycles?

Answer. 31.8 ohms.

Calculation: Apply the capacitive reactance formula and insert the given values as follows:

$$X_C = \frac{1}{2\pi f C}, \quad \text{where } f \text{ in cycles} = 1{,}000{,}000 \text{ or } 10^6 \text{ cycles},$$
$$C \text{ in farads} = 0.005 \times 10^{-6}.$$

Therefore

$$X_C = \frac{1}{2 \times \pi \times 10^6 \times 0.005 \times 10^{-6}} = \frac{1}{2 \times 3.1416 \times 0.005} = 31.8 \text{ ohms}$$

3.16. *Question.* State the mathematical formula for the energy stored in the magnetic field surrounding an inductance carrying an electric current.

Answer. The energy stored in the magnetic field about an inductance carrying a current is given by:

$$E = \frac{1}{2}LI^2, \quad \text{where } L = \text{inductance in henrys},$$
$$I = \text{current in amperes},$$
$$E = \text{energy in joules}.$$

3.17. *Question.* What is the current and voltage relationship when inductive reactance predominates in an a-c circuit?

Answer. When inductive reactance predominates in an a-c circuit the current lags the voltage by an angle which approaches 90° as the resistance becomes less and less.

3.18. *Question.* Given a series circuit consisting of a resistance of 4 ohms, an inductive reactance of 4 ohms, and a capacitive reactance of 1 ohm; the applied circuit alternating e.m.f. is 50 volts. What is the voltage drop across the inductance?

Answer. 40 volts.

Computation: See Figure 46. The voltage across any element of a series combination of impedances is equal to the IZ drop for that impedance, where I is the line current and Z is the impedance in ohms.

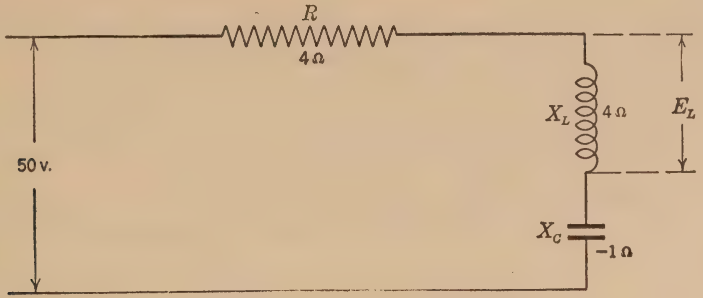


FIG. 46. Problem in a-c circuit theory.

In the given problem:

$$E_L = IZ_L$$

$$I = \frac{E}{Z_{\text{total}}} = \frac{50}{\sqrt{4^2 + (4 - 1)^2}} = \frac{50}{\sqrt{4^2 + 3^2}} = \frac{50}{5} = 10 \text{ amperes}$$

Therefore

$$E_L = 10 \times 4 = 40 \text{ volts}$$

3.19. *Question.* What would be the effect if d.c. were applied to the primary of an a-c transformer?

Answer. There would be no a-c voltage output from the secondary and the primary winding would overheat with possible burnout if protection against excessive current were not provided.

3.20. *Question.* If a power transformer having a voltage step-up ratio of 1 to 5 is placed under load, what will be the approximate ratio of the primary to secondary current?

Answer. The ratio of primary to secondary current will be approximately 5 to 1, or step-down. Since the power is approximately the same in the primary and secondary the current in the secondary decreases in the same ratio as the voltage increases in the secondary.

3.21. *Question.* What factor(s) determine the voltage ratio of a power transformer?

Answer. The turns ratio determines the voltage ratio of a transformer. However, other factors that cause a loss in voltage are copper loss, magnetic leakage, and the regulation of the transformer when under load.

3.22. *Question.* Define "eddy currents."

Answer. "Eddy currents" are currents induced in a core material which set up heat and introduce losses. Eddy currents are also known as Foucault currents.

3.23. *Question.* What is the meaning of "skin effect" in conductors of radio-frequency energy?

Answer. The term "skin effect" refers to the tendency of high-frequency currents to flow along and close to the surface, or skin, of a conductor. As the frequency is increased the skin effect becomes more pronounced. Conductors in the form of tubing, stranded wire, or copper strip are generally used to handle high-frequency energy; in these forms a given amount of copper can be made to provide more surface area. However, for small currents a solid wire is ordinarily satisfactory.

3.24. ***Question.*** **Neglecting distributed capacitance, what is the reactance of a 5 millihenry choke at a frequency of 1,000 kilocycles?**

Answer. 31,416 ohms.

Computation: Apply the formula for inductive reactance with the given values inserted as follows:

$$
\begin{aligned}
X_L &= 2\pi f L, \quad \text{where } 1{,}000 \text{ kc} = 10^6 \text{ cycles, or } f, \\
&\qquad\qquad 5 \text{ millihenrys} = 5 \times 10^{-3} \text{ henry, or } L. \\
&= 2 \times 3.1416 \times 10^6 \times 5 \times 10^{-3} \\
&= 6.2832 \times 10^3 \times 5 = 30.416 \times 10^3 = 30{,}416 \text{ ohms}
\end{aligned}
$$

3.25. ***Question.*** **What is meant by the term "radiation resistance"?**

Answer. "Radiation resistance" refers to that part of an antenna's total resistance which causes a certain amount of loss to the circuit owing to the work done in radiating power.

3.26. ***Question.*** **What is the value of total reactance in a series resonant circuit at the resonant frequency?**

Answer. At series resonance the total reactance of the circuit is equal to *zero.*

3.27. ***Question.*** **Should the number of turns of an inductance be increased or decreased in order to raise the resonant frequency?**

Answer. The number of turns should be decreased.

3.28. ***Question.*** **What is the value of reactance across the terminals of the capacitor of a parallel resonant circuit, at the resonant frequency, and assuming zero resistance in both legs of the circuit?**

Answer. Parallel resonance occurs when the net susceptance is zero. Under these conditions the equivalent reactance is zero. Hence, the reactance measured at the terminals of the capacitor of a parallel resonant circuit is *zero.*

3.29. ***Question.*** **Given a series resonant circuit consisting of a resistance of 6.5 ohms, and equal inductive and capacitive reactances of 175 ohms, what is the voltage drop across the resistance, assuming the applied circuit potential is 260 volts?**

Answer. The voltage drop across the resistor is 260 volts, or the line voltage. This is true because equal inductive and capacitive reactances cancel, the net reactance drop is zero, and the full applied voltage is impressed on the resistor.

3.30. ***Question.*** **Given a series resonant circuit consisting of a resistance of 6.5 ohms, and an equal inductive and capacitive reactances of 175 ohms, what is the voltage drop across the inductance when the applied circuit potential is 260 volts?**

Answer. 7,000 volts.

Computation: The voltage drop across the inductance is equal to the current in amperes through it multiplied by its reactance in ohms, or $E_L = I \times X_L$. In this problem X_L is a given value and I must be computed. Since this is a series circuit the current through the inductance is the same as in the line; therefore proceed to find the line current as follows: The applied voltage E is 260 volts; the reactances being equal will cancel and hence the circuit's resistance is the value of the resistor in the circuit, or 6.5 ohms. Inserting these values, we have

$$I = \frac{E}{R} = \frac{260}{6.5} = 40 \text{ amperes}$$

Now find the voltage drop across the inductance, using the line current, 40 amperes, and the given value of inductive reactance, 175 ohms, thus

$$E_L = I \times X_L = 40 \times 175 = 7{,}000 \text{ volts}$$

3.31. *Question.* Under what conditions will the voltage drop across a parallel tuned circuit be a maximum?

Answer. Assuming a constant current, the voltage across a parallel tuned circuit will be a maximum at resonance.

3.32. *Question.* How may the resonant frequency of an antenna circuit be increased?

Answer. The resonant frequency may be increased by inserting a condenser in series with the antenna, or by shortening its length, or by reducing the number of turns on the antenna inductor.

3.33. *Question.* Draw a simple schematic diagram showing a method of coupling a modulator tube to a radio-frequency power amplifier tube to produce plate modulation of the amplified radio-frequency energy.

Answer. See Figure 47.

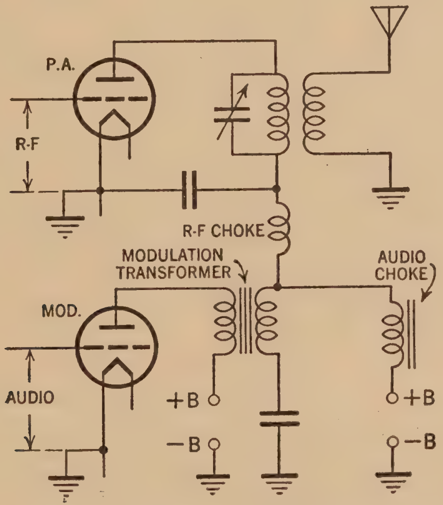


FIG. 47. Illustrating plate modulation.

3.34. *Question.* Draw a diagram of a carrier wave envelope when modulated 50 per cent by a sinusoidal wave. Indicate on the diagram the dimensions from which the percentage of modulation is determined.

Answer. See Figure 48.

3.35. *Question.* Draw a diagram of a microphone circuit complete with two stages of audio amplification.

Answer. See Figure 49.

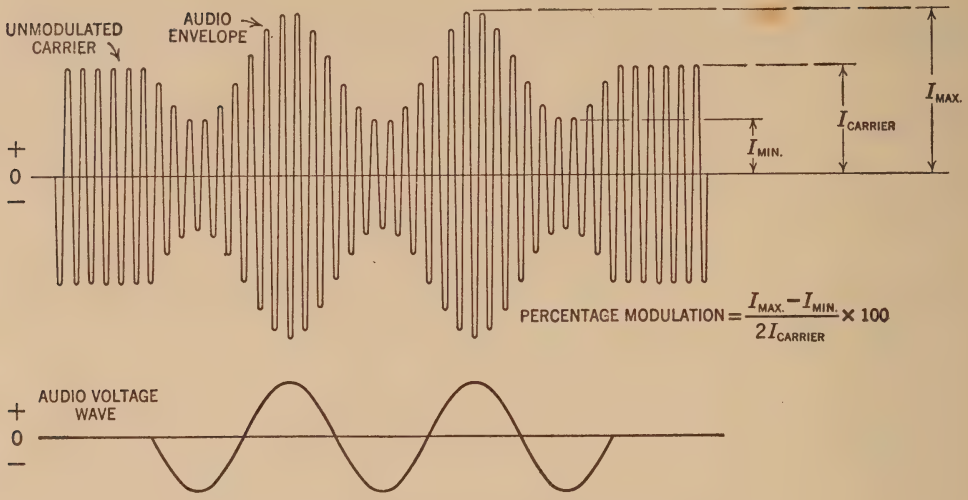


FIG. 48. Carrier wave modulated 50 per cent.

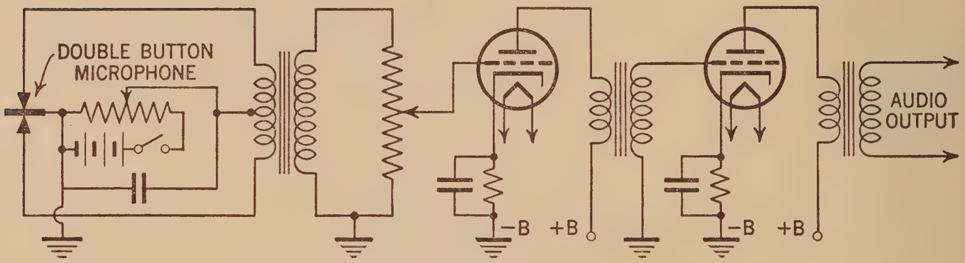


FIG. 49. Microphone with two audio-frequency stages.

3.36. ***Question.*** **Draw a simple schematic diagram showing a Heising modulation system capable of producing 100 per cent modulation. Indicate power supply polarity where necessary.**

Answer. See Figure 50.

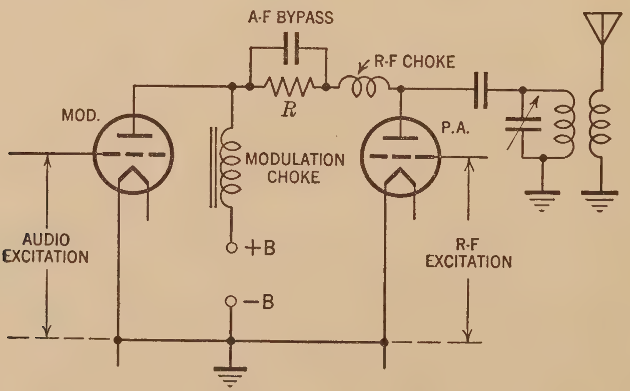


FIG. 50. Heising circuit which provides 100 per cent modulation.

3.37. *Question.* Draw a simple schematic diagram showing a method of suppressor grid modulation of a pentode type vacuum tube.

Answer. See Figure 51.

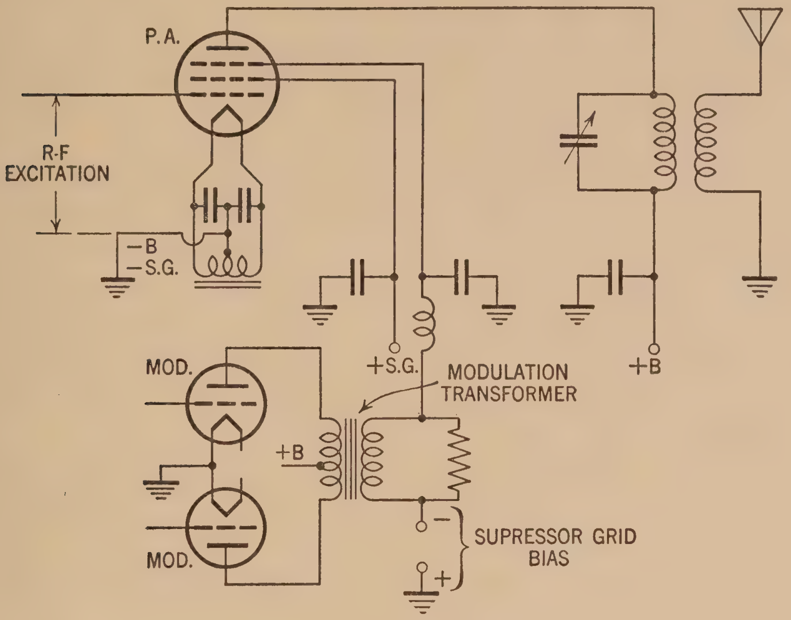


Fig. 51. Suppressor grid modulation.

3.38. *Question.* Draw a simple schematic diagram showing a method of coupling a modulator tube to a radio-frequency power amplifier tube to produce grid modulation of the amplified radio-frequency energy.

Answer. See Figure 52.

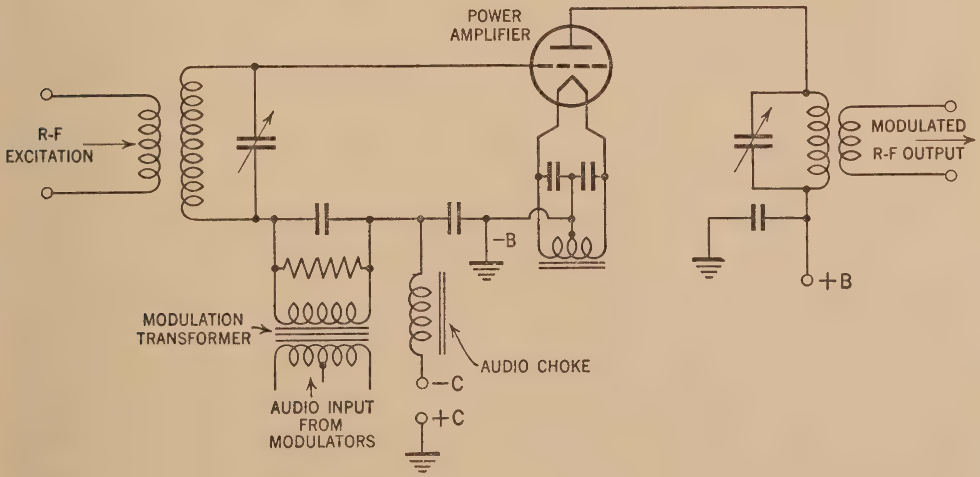


Fig. 52. Grid modulation.

3.39. *Question.* What is meant by "frequency shift" or "dynamic stability" with reference to a modulated radio-frequency emission?

Answer. Frequency shift, called dynamic instability, means that the carrier frequency has changed during modulation. A power supply with poor regulation might cause this condition.

3.40. *Question.* In radiotelephony, what is meant by "the process by which the amplitude of the carrier wave is varied in accordance with the speech or other signal to be transmitted"?

Answer. The expression refers to "amplitude modulation."

3.41. *Question.* What is meant by "high level" modulation?

Answer. High level modulation is modulation produced at a point in a system where the power level approximates that at the output of the system. (F.C.C. Rules and Regulations 2.33.)

3.42. *Question.* What is meant by "grid modulation"?

Answer. Grid modulation is modulation produced by introduction of the modulating wave into any of the grid circuits of any tube in which the carrier frequency is present. (F.C.C. Rules and Regulations 2.34.)

3.43. *Question.* Define "plate modulation."

Answer. Plate modulation is modulation produced by introduction of the modulating wave into the plate circuit of any tube in which the carrier frequency is present. (F.C.C. Rules and Regulations 2.33.)

3.44. *Question.* Describe the construction and characteristics of a "dynamic" type microphone.

Answer. A dynamic microphone is the moving coil type. The diaphragm on which the sound waves impinge is suitably connected to the armature coil which is mounted between the poles of a strong permanent magnet. The e.m.f. induced in the coil as it moves in the magnetic field is the source of the audio voltage that passes on to the amplifiers. A dynamic microphone has excellent frequency response extending over a wide range from 60 to 10,000 cycles; it is a low impedance type of microphone which permits it to be located some distance from its amplifier; it can stand considerable rough treatment as compared with other types and hence is suitable in applications where the microphone is moved while in operation.

3.45. *Question.* Describe the construction and characteristics of a "ribbon" type microphone.

Answer. In the ribbon microphone a thin corrugated strip, or ribbon, of duraluminum, or equivalent, is hung in a strong magnetic field. This short length of ribbon is placed between the poles of a permanent magnet with its length perpendicular to, and its width in the plane of, the magnetic lines of force, so that the edges of the ribbon cut the lines as it is driven back and forth by the sound waves. The motion of the ribbon varies as the velocity in accordance to the frequency and amplitude of the sound waves. There is no diaphragm used in the general meaning of the term. A ribbon type microphone has excellent frequency response covering a wide range from approximately 60 to 10,000 cycles; it is fairly rugged; it has low impedance; moving it while in operation causes considerable noise, owing to ribbon vibration; sounds from the front, or operating side, and along an axis perpendicular to the plane of the ribbon have the maximum effect.

3.46. *Question.* Describe the construction and characteristics of a condenser type microphone.

Answer. The condenser microphone consists of a tightly stretched thin metal diaphragm mounted close to a heavy metal plate which serves as a second plate of the condenser. The air space separating the diaphragm from the metal plate is the dielectric, which acts also to dampen the vibrations of the diaphragm so that it will not set up independent movements of its own and thus accentuate certain frequencies more than others. The small plate area and general construction provide a condenser with a rather low capacitance, in the order of 400 micromicrofarads. A polarizing voltage of a few hundred volts d.c. is used to set up the electrostatic capacity between the plates. Sound waves in striking the diaphragm cause variations in the condenser's capacitance which provides the audio voltage to be amplified. A condenser type microphone is practically free of distortion, hissing, or interfering noises; it has a high impedance and requires a preamplifier which is usually a small three-stage amplifier mounted close by in the head of the microphone; it is not rugged and must be handled with care; it has high fidelity owing to its extremely good high-frequency response.

3.47. *Question.* What is meant by "low level" modulation?

Answer. Low level modulation is modulation produced at a point in a system where the power level is low compared with the power level at the output of the system. (F.C.C. Rules and Regulations 2.32.)

3.48. *Question.* Which type of commonly used microphone has the greatest sensitivity?

Answer. Carbon type microphone.

3.49. *Question.* Describe the construction and characteristics of a "crystal" type microphone.

Answer. In the crystal microphone the audio voltage is obtained from a group of thin crystal cells, usually of Rochelle salt, owing to their piezoelectric properties. A diaphragm suitably connected to electrodes applies mechanical pressure to the crystal unit and in turn an e.m.f. is developed across the crystal surfaces; this e.m.f. is the audio voltage which corresponds to the sound waves and goes to the amplifier. Since the e.m.f. across a single crystal cell is small it requires an arrangement of several such cells to provide efficient results. A crystal type microphone has extremely good high-frequency response and therefore has high fidelity; it is a high impedance type; it is not very rugged and hence must be handled with care.

3.50. *Question.* Describe the construction and characteristics of a "carbon button" type microphone.

Answer. In a carbon button type microphone the diaphragm is arranged to cause its vibrations in turn to vary the contact resistance of carbon granules which fill a small container, or cup. The whole is called a "carbon button." A carbon backing-plate rests against a gold-plated area on the diaphragm so that mechanical pressure is imparted to the granules in the cup and the diaphragm, usually of duraluminum, is tightly stretched and damped. A carbon button microphone possesses the highest sensitivity of any type of commonly used microphone; it has an inherent disadvantage in that its granules cause a frying or hissing noise, which may be objectionable unless the sound level is high, and in some cases it may restrict the amount of amplification possible; it is fairly rugged, but the carbon granules are subject to packing or freezing, a condition caused by excessive current or excessive mechanical pressure on the granules; it has a poor frequency response which is flat up to approximately 1,000 cycles, then shows a rising characteristic up to about 6,000 cycles, and for frequencies above this level the response drops off sharply; it is more generally used for remote pick-up work, or in relay broadcasting of outdoor events and not for regular studio pick-up where high fidelity is required.

3.51. *Question.* **What is a "velocity" type microphone?**

Answer. A velocity type microphone is a form of ribbon type microphone. In this type a very thin strip, or ribbon, is suspended between the poles of a powerful permanent magnet. The ribbon is so light that its motion varies as the velocity component of a sound wave, and the ribbon therefore does not have a pressure built up on it like a typical diaphragm which acts as an obstruction in the path of a sound wave.

3.52. *Question.* **What might be the cause of variations in plate current of a "class B" type of modulator?**

Answer. The plate current of a class B modulator varies during modulation even under normal conditions of operation. The audio drive on a modulator grid is not a voltage wave of constant amplitude but actually the amplitude varies in a complex manner causing the plate current to vary irregularly according to the peculiarities of a given signal.

3.53. *Question.* **What is the relationship between the average power output of the modulator and the modulated amplifier plate circuit input, under 100 per cent, sinusoidal plate modulation?**

Answer. The average power output of the modulator is equal to one-half, or 50 per cent, of the modulated amplifier plate circuit input.

3.54. *Question.* **What would be the effect of a shorted turn in a class B modulation transformer? In a class A modulation transformer?**

Answer. In either class of operation a shorted turn would change the voltage ratio and cause severe distortion. However, of more importance is the fact that a large circulating current would flow in the shorted turn resulting in excessive heat, damaged insulation with possible burnout, and a ruined transformer.

3.55. *Question.* **Why is a high percentage of modulation desirable?**

Answer. A high percentage of modulation provides a greater useful power, or sideband power, for a given carrier power, which means that the signal will cover a wider service area. Then again, at the receiving end a signal with a greater ratio of sideband power is less likely to suffer from interference. The plate efficiency is greater with high percentage modulation, and this is desirable from the standpoint of economy. The use of high percentage modulation causes the sidebands to reach out and this has the effect of lessening the interference in certain areas where a carrier otherwise existing alone would serve no useful purpose and would only cause adjacent channel interference.

3.56. *Question.* What are some of the possible results of overmodulation?

Answer. Overmodulation results in the generation of additional sidebands, or harmonics, which broadens the frequency band and causes the transmission to interfere on adjacent channels. Serious distortion of the modulation envelope also results because the carrier during moments is brought to zero and hence is interrupted.

3.57. *Question.* What might cause frequency modulation in an amplitude modulated radiotelephone transmitter?

Answer. Frequency modulation might be due to poor regulation in a common power supply, which would cause the oscillator to be modulated at the modulating frequency. Another cause might be from heavy load changes on the oscillator if the buffer stages do not effectively isolate the oscillator from the succeeding modulated r-f amplifiers. If r.f. feeds back into the oscillator plate supply it might cause this trouble. In general, circuits and tubes which are subject to heavy load changes might cause frequency modulation.

3.58. *Question.* What percentage of antenna current increase should be expected between unmodulated conditions and 100 per cent sinusoidal modulation?

Answer. The antenna current should increase 22.5 per cent.

Discussion. On full modulation the power increases 50 per cent, and the total is then 150 per cent; thus, 50 per cent is represented in the sidebands and 100 per cent in the carrier. The current then is equal to the square root of 150, or 122.5 per cent, of which 100 per cent represents the carrier current and 22.5 per cent the rise above the carrier value due to full modulation.

3.59. *Question.* Under 100 per cent modulation conditions, what is the ratio of peak antenna current to unmodulated antenna current?

Answer. The peak antenna current is double the unmodulated antenna circuit.

3.60. *Question.* Under 100 per cent modulation conditions, what is the ratio of peak antenna power to unmodulated antenna power?

Answer. The peak antenna power is four times the unmodulated antenna power.

Discussion. Since the instantaneous peak current is twice the carrier current at full modulation and the antenna resistance is a constant and $P = I^2R$, then if I is doubled, or $P = (2 \times I)^2R$, the power is increased four times.

3.61. *Question.* What might be the cause of a decrease in antenna current of a high level amplitude modulated radiotelephone transmitter when modulation is applied?

Answer. A decrease in antenna current during modulation is called downward modulation, and also commonly referred to as downward kick since the ammeter in the antenna circuit would deflect, or kick, downward. The following is a general grouping which suggests the seat of the trouble and the probable cause:

Operating voltages	Insufficient bias. Low filament voltage.
Power supply	Poor regulation. Defective output condenser in filter.

Tubes	Low filament emission.
Circuit adjustments	Improper neutralization.
	Improper tuning.
	Improper loading of modulator; for example, plate circuit resistance of modulated r-f amplifier too high or too low.
Audio system	Distortion.
	Insufficient audio power from modulator.
Excitation	Insufficient in case of class C.
	Excessive in case of class B.

3.62. *Question.* **How should a regenerative receiver be adjusted for optimum response to a weak unmodulated carrier?**

Answer. Adjust the regeneration control to a point just beyond where oscillation starts, tighten the coupling between the primary and secondary, and tune these circuits carefully.

3.63. *Question.* **If a regenerative receiver oscillates too freely with minimum tickler coupling, what adjustment would reduce the feedback?**

Answer. The amount of feedback could be reduced by lowering any of the operating voltages, filament voltage, screen voltage, or plate voltage. Also, tightening the coupling between the primary and secondary tuned circuits will cause the primary to take more r.f. from the secondary, and this loss to the secondary or grid circuit would reduce feedback.

3.64. *Question.* **Why is it necessary to use an oscillating detector for reception of an unmodulated carrier?**

Answer. An oscillating detector generates a frequency different from the incoming frequency and the two frequencies heterodyne, or beat together, to produce a third frequency, or beat frequency, which can be made to come within the audio range to make the signal audible. An unmodulated carrier could not be made audible if the detector did not generate a different frequency because the carrier alone would merely result in a steady plate current with no audio component.

3.65. *Question.* **What is the purpose of shielding in a multistage receiver?**

Answer. Shielding isolates the high-frequency stages electrostatically, which increases the stability of the receiver. That is to say, without shielding the electrostatic coupling existing between the various elements of the tuned circuits would cause feedback and regeneration resulting in the stages breaking into oscillation when operated at maximum gain.

3.66. *Question.* **Explain what circuit conditions are necessary in a regenerative receiver for maximum response to a modulated signal.**

Answer. The tuned circuits should be adjusted closely to resonance and the regeneration control should be set for maximum regeneration, which is a point just on the verge of oscillation or, practically speaking, just before the rushing sound, or "hiss," begins which indicates that the tube is about to spill over and break into oscillation. Keep the adjustment below this "hiss" which is the critical point.

3.67. *Question.* **What feedback conditions must be satisfied in a regenerative detector for most stable operation of the detector circuit in an oscillating condition?**

Answer. Sufficient energy must be fed back from plate to grid, or more than will just make up for the grid circuit losses so that tuning and coupling adjustments will not take the detector out of oscillation. It should be possible to have a smooth control over regeneration so that circuit adjustments are not critical.

3.68. *Question.* **What are the advantages to be obtained from adding a tuned radio-frequency amplifier stage ahead of the first detector (converter) stage of a superheterodyne receiver?**

Answer. Several advantages are to be obtained from the use of a pre-selector stage as follows:

(*a*) Response to image frequencies is reduced.
(*b*) Noise-to-signal ratio is reduced.
(*c*) Greater selectivity owing to added tuned circuits.
(*d*) Higher sensitivity owing to amplification of pre-selector stage.
(*e*) No radiation of local oscillator frequency causing interference.

3.69. *Question.* **What feedback conditions must be satisfied in a regenerative detector in order to obtain sustained oscillations?**

Answer. Sustained oscillations in a regenerative detector depend for one thing on the plate circuit feeding back sufficient r-f power to the grid to overcome the losses in the circuit. Another requisite is that the feedback voltage must be correct in phase, that is, the potential returned to the grid by a change of plate current must be in phase with the grid potential that caused this change of plate current. This is why a regenerative detector will not oscillate if the connections to the tickler coil are reversed. When more energy is added to the grid circuit by feedback than is normally dissipated by the resistance of the circuit the net effect is similar to a circuit whose inherent resistance, or positive resistance, could be decreased; this resistance characteristic is referred to as negative resistance and, therefore, when the feedback is sufficient to cause the negative resistance to compensate the positive resistance oscillations will be generated.

3.70. *Question.* **How is "automatic volume control" accomplished in a radio receiver?**

Answer. In a system of automatic volume control the circuit is arranged so that the incoming signal, after being amplified in the r-f stages, is passed through a diode rectifier with suitable filters for separating the r-f and a-f components. The rectified radio-frequency current in flowing through a resistor, shunted by a condenser, sets up a d-c voltage across this R-C combination which is proportional to the current; the grid returns of the r-f amplifiers connect to the negative potential end of the resistor and, therefore, changes of current intensity through it will vary the bias and control the amount of amplification. If the signal level increases, a larger current flows in the resistor which increases the bias and lowers the amount of amplification; a reduction of signal strength decreases the bias, which allows a greater amplification. Hence, as the signal level goes up or down the change of bias on the r-f stages automatically keeps the volume at a constant level.

3.71. ***Question.*** **If a superheterodyne receiver is tuned to a desired signal at 1,000 kilocycles, and its conversion oscillator is operating at 1,300 kilocycles, what would be the frequency of an incoming signal which would possibly cause "image" reception?**

Answer. A 1,600 kilocycle signal would probably cause image reception. On the assumption that the conversion oscillator tracks at a higher frequency than the desired signal, then the image frequency is equal to the sum of the desired signal frequency and twice the intermediate frequency, or $1{,}000 + (2 \times 300) = 1{,}600$ kilocycles.

3.72. ***Question.*** **If a tube in the only radio-frequency stage of your receiver burned out, how could temporary repairs or modifications be made to permit operation of the receiver if no spare tube is available?**

Answer. The antenna lead-in connection could be removed from the antenna post and reconnected to the plate lead at the defective tube's socket, thus making the primary of the r-f transformer serve as an antenna coupling coil. A blocking condenser could be used in series with the lead-in connection to keep high-voltage d.c. off the antenna and prevent possible short circuit to ground which would short the power supply.

3.73. ***Question.*** **What are the characteristics of "plate detection"?**

Answer. In plate detection the grid is biased approximately to cutoff, similar to class B operation of an amplifier, so that with strong signals the output is linear. Hence, the tube can handle strong signals with comparatively low distortion, but its sensitivity is only fair.

3.74. ***Question.*** **What is the purpose of a "radio-frequency" choke?**

Answer. The most common use of a radio-frequency choke is to supply a high inductance in a circuit for the purpose of suppressing an undesired frequency and permitting other frequencies to pass, or perhaps suppress a radio-frequency current and allow direct current to pass, as in grid bias and plate power supply circuits. Another use is in an impedance-capacitive coupled stage where a radio-frequency choke might serve as a load in the plate circuit.

3.75. ***Question.*** **What would be the effect upon a radio receiver if the vacuum tube plate potential were reversed in polarity?**

Answer. The receiver would become inoperative because plate current could not flow with negative potential on the plates.

3.76. ***Question.*** **What would be the effect upon the operation of a receiver if the grid return is connected to the positive rather than the negative terminal of the filament battery?**

Answer. The signal probably would be only slightly affected in many receivers because of the small net change in the bias. However, in early types of regenerative receivers which used no r-f amplification this change would ordinarily interfere with normal reception; the signal would be very weak or inaudible because the potential from this point would oppose the potential set up by a grid-leak and condenser combination.

3.77. *Question.* **Draw a simple schematic diagram of a system of coupling a single electron tube employed as a radio-frequency amplifier to a Hertz type antenna.**

Answer. See Figure 53.

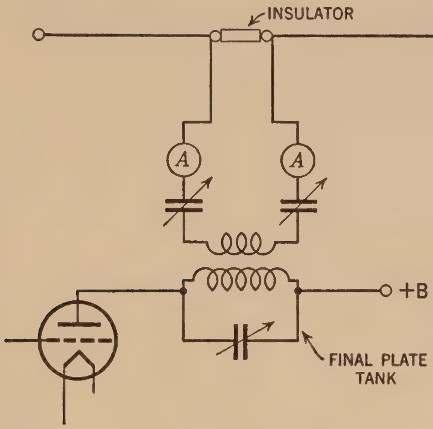


FIG. 53. Hertz antenna coupled to the tank of a power amplifier.

3.78. *Question.* **Draw a simple schematic diagram indicating a link coupling system between a tuned-grid tuned-plate oscillator stage and a single electron tube, neutralized amplifier.**

Answer. See Figure 54.

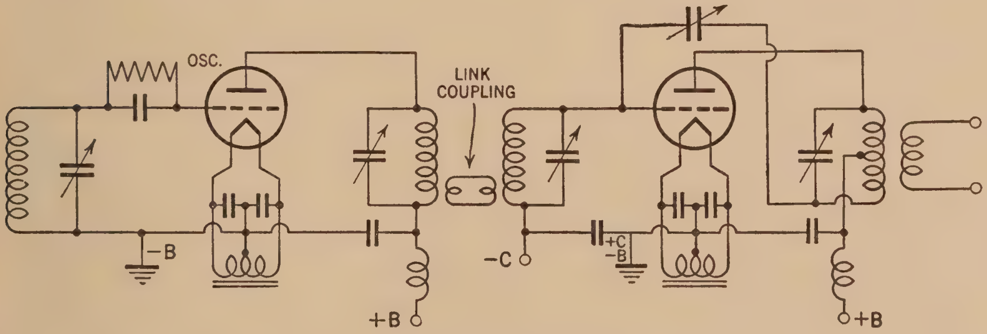


FIG. 54. Example of link coupling.

3.79. *Question.* **Draw a simple schematic diagram of a push-pull, neutralized radio-frequency amplifier stage, coupled to a Marconi type antenna system.**

Answer. See Figure 55.

3.80. *Question.* **Draw a simple schematic diagram of a system of neutralizing the grid-plate capacitance of a single electron tube employed as a radio-frequency amplifier.**

Answer. See Figure 56.

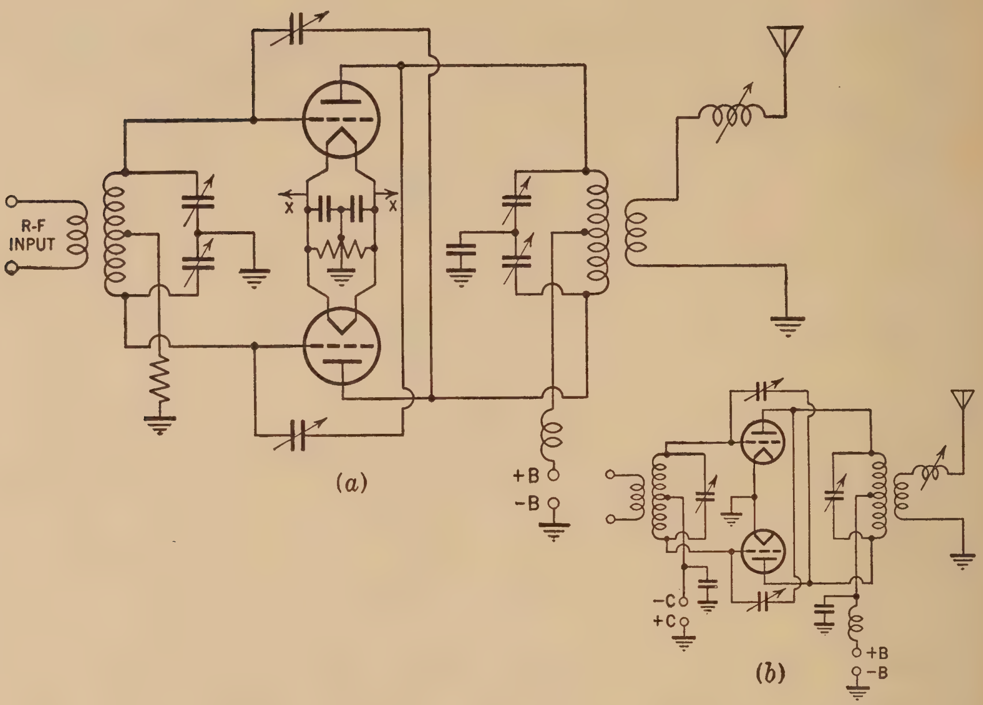


FIG. 55. Push-pull amplifier, neutralized and coupled to the antenna. Either circuit may be used to answer the question.

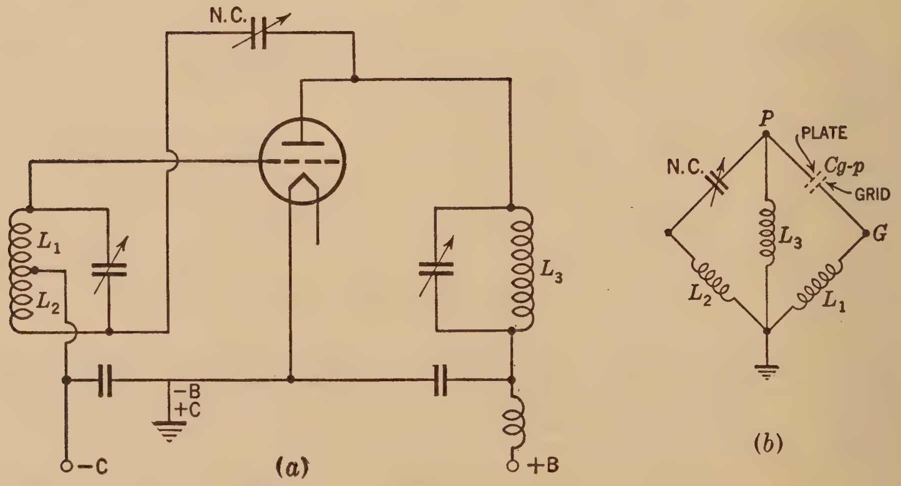


FIG. 56. Neutralization by Rice method. The principles are explained by the bridge diagram in (*b*) where no voltage exists across L_3 when properly neutralized.

3.81. ***Question.*** **Draw a simple schematic diagram showing the proper method of obtaining d-c screen-grid voltage from the plate supply in a modulated pentode, class C amplifier.**

Answer. See Figure 57.

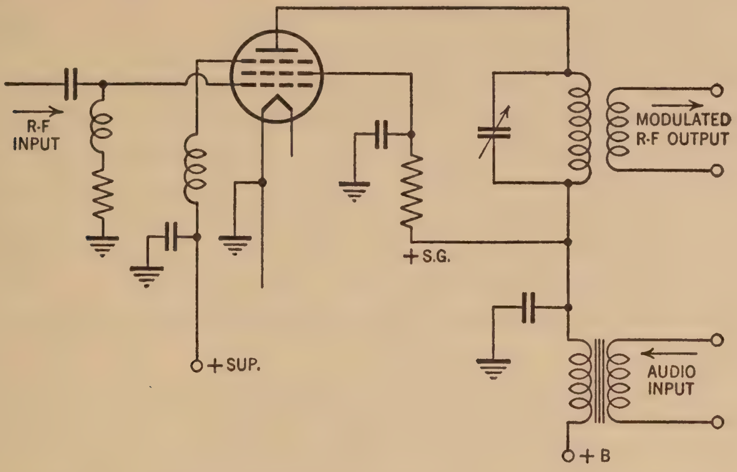


FIG. 57. Showing the screen grid and plate both receiving the modulating voltage.

3.82. ***Question.*** **What is the purpose of a "buffer" amplifier?**

Answer. A buffer amplifier is an r-f amplifier which is operated in a manner to provide adequate plate isolation between a previous stage, or oscillator, and subsequent r-f stages for minimizing circuit reactions that cause frequency instability. One or more buffer stages usually follow the oscillator in a radiotelephone transmitter. By employing loose coupling and operating a buffer stage not primarily for gain it effectively reduces oscillator plate circuit load changes resulting from modulation or plate load changes in the power amplifier.

3.83. ***Question.*** **What are the characteristics of a "frequency doubler" stage?**

Answer. A frequency doubler stage has its plate tank adjusted to the second harmonic of the grid excitation voltage, it operates at a relatively low efficiency and requires no neutralization. In one circuit arrangement the bias is adjusted to a value well beyond cutoff, similar to class C operation, so that only a portion of the least negative half cycle of the grid excitation voltage wave causes a pulse of plate current which excites the tank and owing to its oscillatory properties (flywheel effect) the tank produces two cycles before it again receives excitation. This type of operation generates a strong second harmonic in the output. A frequency doubler stage may be operated with the grids in push-pull receiving the fundamental frequency and the plates in parallel with the plate tank tuned to the second harmonic.

3.84. ***Question.*** **What are the advantages of a master-oscillator power-amplifier type of transmitter as compared with a simple oscillator transmitter?**

Answer. The frequency stability of a transmitter is improved by the use of a power amplifier. Load changes on the oscillator, for example, due to variations in antenna capacitance are minimized by employing one or more r-f amplifier stages which isolate the oscillator from the antenna.

3.85. *Question.* **What are the differences between Colpitts and Hartley oscillators?**

Answer. In the Colpitts type the oscillatory circuit is divided electrically into two capacitances, which permits the grid to receive excitation from one capacitance and the plate to supply excitation to the other for driving the oscillatory circuit. Therefore a Colpitts oscillator, called "split-capacitance" type, uses one capacitance connected between grid and cathode and the other connected between plate and cathode. The Hartley oscillator is the "split-inductance" type in which one coil section of the oscillatory circuit inductance connects to grid and cathode and the other coil section between plate and cathode for similar purposes of excitation as in the Colpitts oscillator.

3.86. *Question.* **What is the primary purpose of a grid-leak in a vacuum tube transmitter?**

Answer. The primary purpose of a grid-leak is to furnish a conductive path of high resistance for electrons to flow back to cathode. Specifically, a grid-leak may serve as a source of bias, as in the self-bias method, or if separate biasing is used the grid-leak would connect the grid to the bias source, assuming the bias voltage to be shunt fed to the grid, thus making necessary the use of a grid blocking condenser. The grid of any electron tube must be provided with a direct-current path of some kind to its cathode and if this conductive path were open and continuity broken for any reason it would trap electrons on the grid, thus building up a negative blocking potential.

3.87. *Question.* **By what means is feedback coupling obtained in a tuned-grid tuned-plate type of oscillator?**

Answer. The capacitance between the plate and grid within the tube furnishes the necessary coupling by which r-f power in the output feeds back to the input to cause oscillation.

3.88. *Question.* **What may be the result of parasitic oscillations?**

Answer. Parasitic oscillations may cause overheating of circuit components and tube elements, a distorted output, erratic action in the r-f circuits, the radiation of spurious frequencies, and a general decrease in efficiency.

3.89. *Question.* **How may the production of harmonic energy by a vacuum tube radio-frequency amplifier be minimized?**

Answer. First, in considering the *operation* of a radio-frequency amplifier the harmonic output is minimized by careful attention in maintaining proper bias and preventing over-excitation. Second, in considering the *methods* employed to minimize harmonic output there are several means as suggested by the following: Operating the r-f stage in push-pull; minimizing electrostatic coupling in the output transformer by a Faraday screen, or electrostatic shield; absorption of harmonics by harmonic suppressor or filter in the circuit; reducing harmonic transfer by a link coupling system between stages in which one leg of the link circuit is grounded.

3.90. *Question.* **What is the definition of "parasitic oscillations"?**

Answer. Parasitic oscillations are high-frequency currents generated in an r-f amplifier which bear no relation to the desired frequencies in the stage. These spurious oscillations are usually generated at a very high frequency because their presence is due to the forming of oscillatory circuits by chokes or connection leads which supply the inductance together with distributed capacitance in coils or stray capacity effects in circuit wiring or between circuit elements.

3.91. *Question.* What is the purpose of a "Faraday" screen between the final tank inductance of a transmitter and the antenna inductance?

Answer. The purpose of a "Faraday" screen is to minimize harmonic radiation. The screen effectively reduces the electrostatic coupling between the two windings, which practically eliminates second harmonic frequencies being transferred to the antenna by this means, the normal coupling being electromagnetic passes the working frequency.

3.92. *Question.* How may the distortion effects caused by class B operation of a radio-frequency amplifier be minimized?

Answer. Distortion in a class B radio-frequency stage may be minimized by operating at the proper bias and proper excitation to keep the output linear, by observing the proper procedure in tuning the tank circuits, by operating the stage in push-pull, and by preventing excessive load on the output.

3.93. *Question.* What is the effect of carrier shift in a plate modulated class C amplifier?

Answer. Carrier shift causes the following: adjacent channel interference owing to generation of additional sideband frequencies; distortion of modulation; lower power output; broadens the tuning of the wave.

3.94. *Question.* What are some possible indications of a defective transmitting tube?

Answer. The plate may show excessive color in a "soft" tube due to high plate current and overheating. A blue glow or haze seen within the envelope might result from a gassy tube. A burned-out filament, obviously, would give no light with voltage applied. Another possible indication is subnormal plate current caused by a low emission filament. Shorted electrodes would probably show sparking.

3.95. *Question.* What would be the possible indications that a vacuum tube in a transmitter has subnormal filament emission?

Answer. A low emission filament would result in subnormal plate current and low output, conditions which would be indicated by low readings, respectively, on the plate current meter and antenna ammeter. If the tube were being worked as an oscillator it might be incapable of oscillating with a low emission filament.

3.96. *Question.* What are possible causes of negative carrier shift in a linear radio-frequency amplifier?

Answer. Negative carrier shift means that the amplitudes of the negative halves of the modulation wave are greater than the positive halves and, consequently, the carrier power shifts downward. The following might cause this condition:

Poor regulation of the power supply.
Audio wave distorted owing to overexcitation in modulator stage.

Improper bias on modulator stage.
Low filament emission.
Overmodulation, although this condition, in some cases, might cause an upward shift.
Improper circuit conditions, such as, improper load, detuned antenna, and tank circuits improperly tuned.

3.97. *Question.* **In a modulated class C radio-frequency amplifier, what is the effect of insufficient excitation?**

Answer. Insufficient r-f excitation in a modulated class C amplifier will reduce the output and lower the efficiency.

3.98. *Question.* **What is the purpose of a "dummy antenna"?**

Answer. A dummy antenna, or artificial antenna, is a substitute antenna which permits a transmitter to be fully operated without radiating power that might cause interference. For example, a dummy antenna serves a practical need where a transmitter is to be adjusted or warmed up prior to going on the air, or for experimental or test purposes where an unlicensed transmitter is to be operated with power on.

3.99. *Question.* **In a class C radio-frequency amplifier stage of a transmitter, if plate current continued to flow and radio-frequency energy is still present in the antenna circuit, what defect would be indicated?**

Answer. Defective blocking bias conditions might permit oscillation which would continue to excite the antenna when the stage otherwise should be inoperative. Another possibility would be due to unneutralized conditions causing self-oscillation in the stage if the excitation was not being applied but antenna current was present.

3.100. *Question.* **If the transmitter filament voltmeter should cease to operate, how may the approximately correct filament rheostat adjustment be found?**

Answer. A fairly close adjustment of filament voltage could be found by observing a plate current meter for normal indication, or in the absence of a plate current meter the proper adjustment could be judged approximately by normal brightness of the filament.

3.101. *Question.* **What are some possible causes of overheating vacuum tube plates?**

Answer. Some possible causes of an overheated plate are a soft or gassy tube, parasitic oscillations, unneutralized condition, insufficient bias, excessive plate voltage, and detuned plate circuit.

3.102. *Question.* **Should the plate current of a modulated class C amplifier stage vary or remain constant under modulation conditions? Why?**

Answer. In a class C amplifier stage the plate current should remain constant during modulation. If there is no distortion present the positive and negative halves of the modulation or audio cycle result in equal increases and decreases of plate current. Since the audio cycle swings symmetrically about the d-c plate current component as a zero axis the average value of the plate current remains unchanged.

3.103. *Question.* What is the effect of a swinging antenna upon the output of a simple oscillator?

Answer. The effect of a swinging antenna is to vary the frequency since changes in antenna capacitance act to vary the load on the oscillator plate circuit. Frequency instability is a characteristic of all simple oscillator-type transmitters in which the oscillator is coupled into the antenna.

3.104. *Question.* What factors permit high conduction currents in a hot-cathode type of mercury-vapor rectifier tube?

Answer. In a mercury-vapor rectifier tube the ionization of the vaporized gas and neutralization of the negative space charge are inherent characteristics which account for electrons in great quantities being made available for conduction through the tube. These actions in turn account for the tube having a low internal impedance, and low voltage drop, which is practically constant at 15 volts for all normal values of current handled by the tube. Since the voltage drop is very low and remains practically constant the I^2R loss, or dissipation, does not become excessive on high currents.

3.105. *Question.* List the principal advantages of a mercury-vapor rectifier over a high-vacuum type of rectifier.

Answer. The principal advantages of a mercury-vapor rectifier over a high-vacuum type of rectifier are lower internal impedance, which provides better voltage regulation, and lower I^2R loss, which gives a higher efficiency.

3.106. *Question.* What effect does the resistance of filter chokes have on the regulation of a power supply?

Answer. The effect is that by decreasing the resistance of filter chokes the regulation is improved.

3.107. *Question.* Describe the theory of current conduction and rectification by means of cold cathode, gassy diode vacuum tubes.

Answer. The theory of **current conduction** in a gaseous type diode tube is based on the ionization of the gas when electrons collide with or bombard the gas atoms, which leaves these atoms in a positively charged state through losing electrons by this action. The positive atoms, or ions, seek a negative electrode to take on the same number of electrons they lost owing to ionization, whereas, the electrons which were freed by collision go toward the positive electrode and represent the conduction current. The **rectifying action** when utilizing a cold cathode depends for one thing upon the difference in size of the two electrodes, one electrode being much larger than the other and, also, upon the difference in magnitude between a positive atom and an electron which is infinitely smaller in comparison. In this action only a relatively few electrons leave the smaller electrode in order to neutralize the limited mass of ions around its surface, but the larger electrode does not hold such restrictions. Therefore, when an alternating-current voltage is applied to two such electrodes it results in practically one-way conduction, or rectification. Conduction is obtained on the half cycle when the smaller electrode is at a positive potential and the larger one at a negative potential, but on the next half cycle the potentials are reversed and there is practically no conduction. Although a rectifier of this kind does not give 100 per cent rectification, yet it serves effectively in many practical applications.

3.108. *Question.* **Describe the principle of operation of a synchronous type of mechanical rectifier.**

Answer. In one type of synchronous mechanical rectifier an electromagnet, provided with an armature carrying suitable contacts, is energized by an alternating current which causes the armature to vibrate in synchronism with the a-c supply. The contacts are arranged so that one pair closes on one swing of the armature to connect the line to the load to provide a pulse of current of the desired d-c polarity, and on the opposite swing of the armature this pair opens and another pair closes to keep the same polarity across the load as for the first pulse. Another type employs a synchronous motor which drives a commutator with contacts suitably arranged with respect to stationary and rotary segments so that the connections are mechanically reversed for each half cycle of the a-c supply to provide a d-c voltage to the load.

3.109. *Question.* **What might be the result of starting a motor too slowly, using a hand starter?**

Answer. The high current, if continued too long by slow starting of a motor, will overheat the armature and the starting resistors. A motor running at slower speeds develops less counter e.m.f. to limit the current taken by the armature, and, therefore, when a motor is started too slowly the current flows at a high value over a longer period of time.

3.110. *Question.* **State the principal advantage of a "third brush" generator for radio power supply in automobiles.**

Answer. The use of a third brush from which the field excitation is obtained results in a great improvement in the voltage regulation of the generator. This advantage is important in a generator used to charge the radio battery in an automobile which is operated under widely varying speed conditions. The third brush can be adjusted to keep the charging voltage within the desired maximum limits, which prevents excessive charging currents at high speeds.

3.111. *Question.* **What materials should be used to clean the commutator of a motor or generator?**

Answer. The materials used to clean a commutator are a fine grade of sandpaper, about No. 0000, and a pad made of canvas or duck. *Emery cloth should never be used.* Materials such as vaseline and special compounds for cleaning commutators should be used only when especially recommended.

3.112. *Question.* **List three causes of sparking at the commutator of a d-c motor.**

Answer. Several causes of sparking at the commutator of a d-c motor are dirty commutator, high bars or high mica, overload, starting the motor too fast, defective armature winding, brushes improperly set on neutral point, faulty brush spring tension which may be too light, or the brushes themselves may be either chipped, or worn, or poorly fitted to the commutator.

3.113. *Question.* **Why is it necessary to use a starting resistance when starting a d-c motor?**

Answer. A starting resistance provides a voltage drop in the line which is necessary to limit the current taken by the armature to a safe value until the counter e.m.f. builds up to give the same result. The armature windings of d-c motors generally have very low resistances, much less than an ohm in most cases.

3.114. *Question.* **List the comparative advantages and disadvantages of motor-generator and transformer-rectifier power supplies.**

Answer. Rotating machinery and rectifier type power supplies have comparative advantages and disadvantages as follows:

Motor-generator sets.

Advantages:

Require small filters because of the high ripple frequency.

Can be used for power supply in portable equipment.

Very rugged and less danger of interruption owing to flash-back.

Give long continuous service; maintenance consists normally of only an occasional need for brush replacement and lubricants, which are comparatively inexpensive items.

Disadvantages:

High initial cost.

High installation cost; a motor-generator set usually must be located some distance from the transmitter because of possible troubles due to vibration and some machines are noisy.

Requires frequent and periodic servicing, which includes lubrication and very careful attention to commutator and brushes to prevent flashover troubles.

Repairs are very difficult in the case of breakdown of the armature.

Transformer-rectifier power supplies.

Advantages:

Easy replacement of tubes.

No moving parts.

Service routine is simplified.

Installation is simplified because a rectifier type power supply usually is mounted in the frame as a component part of the transmitter.

Disadvantages:

Tubes have comparatively short useful life.

Replacement costs are high.

Not very rugged; fragile.

Tubes are subject to flash-back, which might ruin them.

Large filters are required.

Cannot be operated from a d-c source.

3.115. *Question.* **If the reluctance of an iron-core choke is increased by increasing the air gap of the magnetic path, in what other way does this affect the properties of the choke?**

Answer. In addition to the reluctance being changed by widening the air gap of the magnetic path, the inductance of the choke is decreased and its effectiveness as a choke might be impaired. Another effect is that a larger current can be carried by the choke without saturation of the core.

3.116. *Question.* **What is the effect upon a filter choke of a large value of direct current flow?**

Answer. A large value of direct current in a filter choke tends to saturate the iron core, reduce the inductance, and impair its effectiveness as a choke. A large current will cause overheating if it exceeds the current rating of the choke.

3.117. *Question.* What are the characteristics of a condenser-input filter system as compared with a choke-input system?

Answer. Comparing a condenser-input filter system with a choke-input system, the condenser-input type has the following characteristics: Higher inverse peak voltage, higher voltage output, and poorer voltage regulation.

3.118. *Question.* What is the principal function of the filter in a power supply?

Answer. The principal function of the filter in a power supply is to smooth out the pulsations of the rectified a-c cycle to provide a substantially steady d-c voltage containing only the permissible amount of ripple frequency.

3.119. *Question.* What are the characteristics of a choke-input filter system?

Answer. The characteristics of a choke-input filter system compared with a condenser-input filter are lower inverse peak voltage, lower voltage output, and better voltage regulation.

3.120. *Question.* What is the percentage regulation of a power supply with a no-load voltage output of 126.5 volts and a full-load voltage output of 115 volts?

Answer. The percentage regulation is 9%.

Computation: Apply the formula for percentage regulation and insert the given values as follows:

$$\text{Regulation in per cent} = \frac{E_{\text{max}} - E_{\text{min}}}{E_{\text{min}}} \times 100 = \frac{126.5 - 115}{115} \times 100 = 9\%$$

3.121. *Question.* What is the definition of "voltage regulation" as applied to power supplies?

Answer. Voltage regulation as applied to power supplies expresses in per cent the voltage drop between no load and full load compared with the full-load voltage, as given by the formula below. (It is to be mentioned that some tube manuals make use of the no-load voltage for comparison with the difference between the no-load and full-load voltages.)

$$\text{Regulation in per cent} = \frac{E_{\text{no load}} - E_{\text{full load}}}{E_{\text{full load}}} \times 100$$

3.122. *Question.* May two condensers of 500 volts, operating voltage, one an electrolytic and the other a paper condenser, be used successfully in series across a potential of 1,000 volts? Explain your answer.

Answer. The condensers in series could not be used successfully across a 1,000-volt **a-c line** because during the half cycle when the polarity was improper the electrolytic would conduct, with the result that it would overheat and, owing to its internal resistance then being negligible, would subject the paper condenser to almost the full 1,000 volts, which might cause it to break down. However, the normal application of an electrolytic condenser is in a **d-c circuit** where an a-c component is present, but even here the series combination could not be used because the internal resistance of an electrolytic condenser is much lower than for a paper condenser. The 1,000 volts d.c. would be distributed in proportion to the respective resistances and consequently a much higher voltage than 500 volts would be applied to the paper condenser, probably causing it to break down.

3.123. ***Question.* What is the principal function of a "swinging choke" in a filter system?**

Answer. The principal function of a "swinging choke" in a filter system is to maintain the necessary inductance, or impedance, at the rectifier output for widely changing load conditions. The inductance of the choke changes with the d-c component as it rises and falls according to the load changes. See answer to Question 5.108.

3.124. ***Question.* What is the purpose(s) of a "bleeder" resistor as used in connection with power supplies?**

Answer. A "bleeder" resistor protects the filter condensers from breakdown because it keeps a load on the rectifier at all times, which prevents dangerous voltage peaks from developing when the regular load is decreased or removed. Incidentally, the use of a bleeder improves the voltage regulation. In addition, it serves as a discharge path for the filter condensers after the equipment is shut down, thus protecting the personnel from possible high-voltage shock.

3.125. ***Question.* What does a blue haze in the space between the filament and plate of a high-vacuum rectifier tube indicate?**

Answer. Blue haze is an indication of ionization due to the presence of gas in the tube. A high-voltage rectifier tube might show a blue haze when operated at excessive voltage but not on normal voltage if only a small trace of gas were present. A high-vacuum tube showing a blue haze under normal operating conditions should be replaced with a good tube.

3.126. ***Question.* When condensers are connected in series in order that the total operating voltage of the series connection is adequate for the output voltage of a filter system, what is the purpose of placing resistors of high value in shunt with each individual condenser?**

Answer. The purpose of connecting a resistor across each condenser unit is to protect the condenser from excessively high voltage, which might damage it. If there is any variance in the internal resistances of the condensers in a series bank the one with the highest internal resistance will have the highest voltage applied to it. Also, the a-c component will cause the peak voltage to be highest across the condenser of lowest capacitance. The resistors, being in series and connected across the line, form practically a voltage divider which allows the line voltage to be distributed proportionally across the condensers to keep them working within safe limits.

3.127. ***Question.* If a high-vacuum type, high-voltage rectifier tube should suddenly show internal sparking and then fail to operate, what elements of the rectifier-filter system should be checked for possible failure before installing a new rectifier tube?**

Answer. The filter should be checked for any short-circuited condition, such as a shorted filter condenser, a shorted bleeder resistor, or a short to ground in the wiring. It is usual practice to check the input filter condenser before looking elsewhere for the trouble since this condenser is across the output of the rectifier tubes and, therefore, is placed under the greatest strain.

3.128. *Question.* **If the plate of a rectifier tube suddenly became red hot, what might be the cause and how could remedies be effected?**

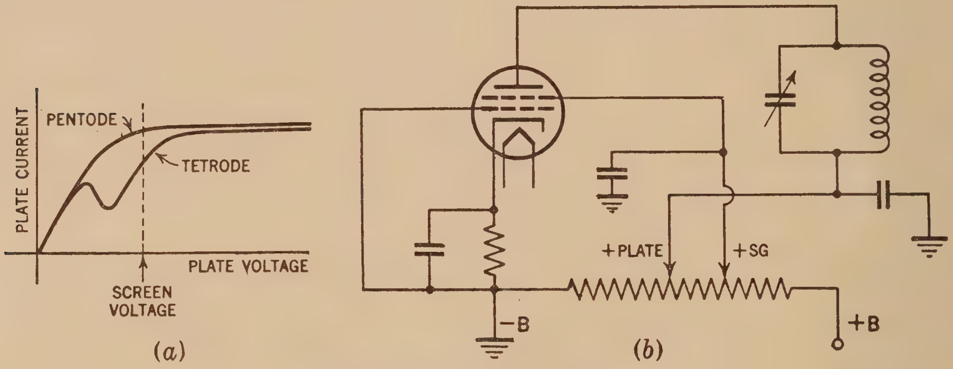
Answer. An overload condition will cause a rectifier tube plate to operate red hot; therefore check for a shorted filter condenser, or shorted bleeder resistor, or short to ground, and clear any shorts or replace any defective parts if found. If the trouble is not in the power supply, check the load circuit for excessive plate current readings in any stage which might cause overload, especially if tuning adjustments were being made at the time without first reducing power.

3.129. *Question.* **Draw a simple schematic diagram of a quartz crystal controlled oscillator, indicating the circuit elements necessary to identify this form of oscillatory circuit.**

Answer. See Figure 6.

3.130. *Question.* **Draw a simple schematic diagram of a dynatron type of oscillator, indicating the circuit elements necessary to identify this form of oscillatory circuit.**

Answer. See Figure 58.



(*a*) (*b*)

FIG. 58. Dynatron oscillator.

3.131. *Question.* **Draw a simple schematic diagram of an oscillatory circuit involving the use of a spark gap discharge, indicating the circuit elements necessary to identify this form of oscillatory circuit.**

Answer. See Figure 59.

3.132. *Question.* **Draw a simple schematic diagram of an oscillating arc circuit, indicating the circuit elements necessary to identify this form of oscillatory circuit.**

Answer. See Figure 60.

3.133. *Question.* **Draw a simple schematic diagram of an electron coupled oscillator, indicating the circuit elements necessary to identify this form of oscillatory circuit.**

Answer. See Figure 9.

3.134. *Question.* **What does the expression "positive temperature coefficient" mean, as applied to a quartz crystal?**

Answer. The expression "positive temperature coefficient" means that the

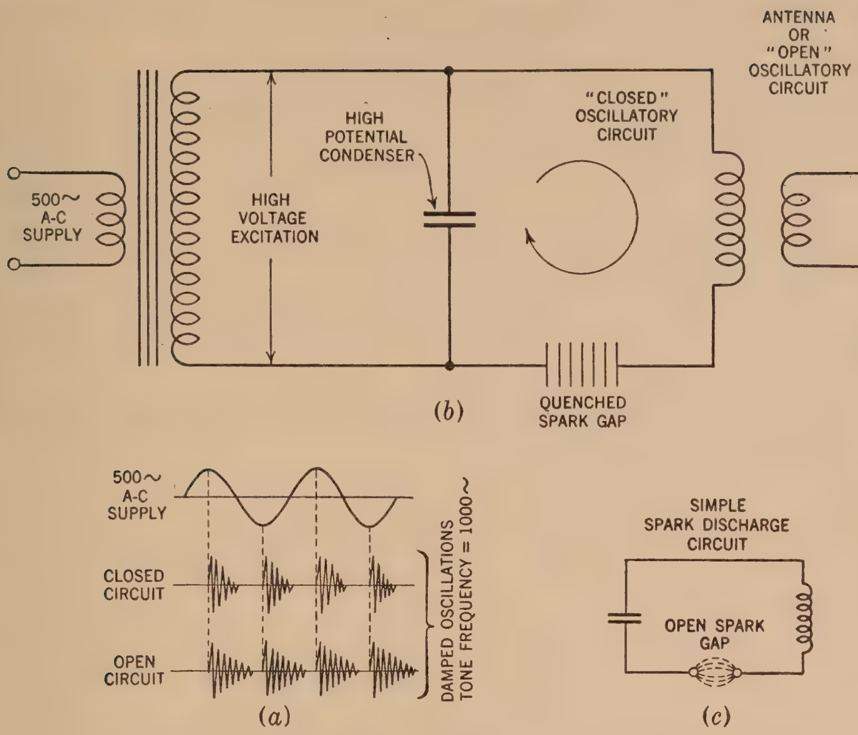


FIG. 59. Spark discharge basic circuit shown in diagram (*c*).

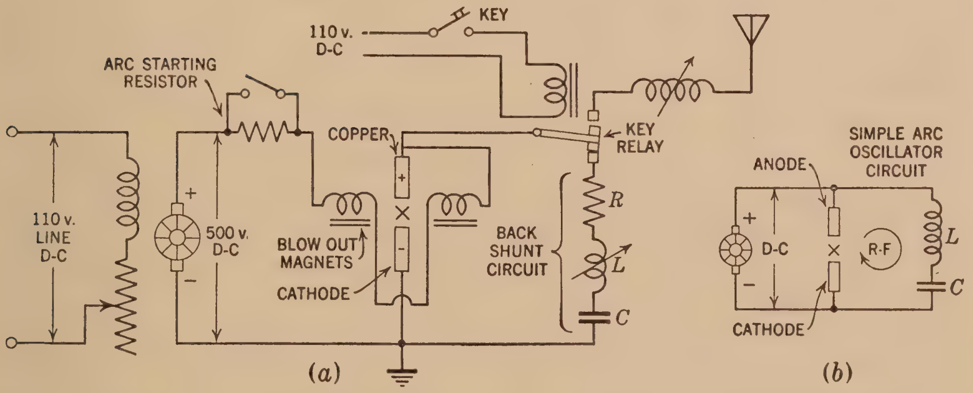


FIG. 60. Sketch (*b*) shows a fundamental arc circuit. Sketch (*a*) shows how a back shunt circuit is connected.

frequency increases as the temperature rises. For example, in a given crystal the frequency may increase 35 to 40 parts in a million for each degree Centigrade of change of temperature. Crystals of the Y-cut type usually have a positive temperature coefficient.

3.135. ***Question.*** **Draw a simple schematic diagram of a crystal controlled vacuum tube oscillator, using a pentode type tube. Indicate power supply polarity where necessary.**

Answer. See Figure 10.

3.136. *Question.* What will result if a d-c potential is applied between the two parallel surfaces of a quartz crystal?

Answer. A crystal with a d-c voltage applied to the opposite plane surfaces will undergo a change in its dimensions; that is, it becomes deformed and remains so until the applied voltage is removed. A large d-c voltage would cause great mechanical strain or a maximum of deformation which might crack or shatter the crystal.

3.137. *Question.* What does the expression "negative temperature coefficient" mean, as applied to a quartz crystal?

Answer. The expression "negative temperature coefficient" means that the frequency increases as the temperature decreases. Crystals of the X-cut type usually have a negative temperature coefficient.

3.138. *Question.* What does the expression "low temperature coefficient" mean, as applied to a quartz crystal?

Answer. A "low temperature coefficient" refers to a crystal which is comparatively free from frequency changes with change in temperature.

3.139. *Question.* What is the function of a quartz crystal in a radio transmitter?

Answer. A quartz crystal dictates the frequency of the master oscillator, which is the source of the frequency assigned to the transmitter. The crystal's special properties improve the frequency stability of the oscillator.

3.140. *Question.* What may result if a high degree of coupling exists between the plate and grid circuits of a crystal controlled oscillator?

Answer. A high degree of coupling between the plate and grid circuits might cause excessive feedback to overload and shatter the crystal or cause the crystal to jump to a different frequency.

3.141. *Question.* What is the purpose in maintaining the temperature of a quartz crystal as constant as possible?

Answer. Temperature control keeps the amount of frequency drift within very narrow limits and assures maintaining the frequency assigned to the transmitter as constant as practicable and within the frequency tolerance limits.

3.142. Question. Why is a separate source of plate power desirable for a crystal oscillator stage in a radio transmitter?

Answer. The frequency stability of the oscillator is improved by the use of a separate plate power supply. A common power supply would allow load changes in the power amplifier stages due to modulation or other causes to react on the oscillator plate circuit which would result in distortion and frequency variation.

3.143. *Question.* What are the principal advantages of crystal control over tuned circuit oscillators?

Answer. Greater frequency stability is the main advantage. The small size of the crystal element permits practical use of temperature control to keep the amount of frequency drift within very narrow limits. A crystal oscillator is comparatively easy to adjust and the high Q properties of the crystal provide greater selectivity. The Q value of a crystal is many times greater than a coil and condenser assembly of much larger dimensions.

3.144. ***Question.*** **What is the approximate range of temperature coefficients to be encountered with X-cut quartz crystals?**

Answer. The range of temperature coefficients to be expected in the use of X-cut quartz crystals is approximately between +100 parts and −22 parts in a million per degree Centigrade. These figures indicate a greater range of change in *parts per million* for temperature increases, which cause the frequency of the crystal to increase.

3.145. ***Question.*** **Is it necessary or desirable that the surfaces of a quartz crystal be clean? If so, what cleaning agents may be used which will not adversely affect the operation of the crystal?**

Answer. It is essential that the surfaces of a quartz crystal be scrupulously clean. A speck of dirt or a greasy film on the face of a crystal may change its characteristics entirely. For this reason it is important that a crystal be carefully cleaned after handling with the fingers, and assembling the crystal in its holder should be done under reasonably dust-free conditions. One of the best cleaning agents is carbon tetrachloride (Carbona).

3.146. ***Question.*** **Explain the generation of radio-frequency oscillations of a spark discharge oscillatory circuit.**

Answer. Refer to Figure 59, which shows a high-voltage transformer, high-potential condenser, spark gap, and inductance. Power is supplied by the transformer at a low frequency, not radio frequency, and the oscillatory circuit consists of the condenser, the inductance, and the gap in series. On an alternation of the power cycle the condenser is charged by the same voltage building up across the gap and when the voltage reaches an amplitude which will break down the high resistance of the gap a spark discharge takes place, thus making the gap conductive. The condenser voltage decreases as it discharges and sends current through the inductance so that during this interval energy is being transferred from electrostatic lines in the condenser to electromagnetic lines surrounding the inductance. When the energy in the condenser is spent the magnetic lines begin to diminish and generate a voltage (that is, e.m.f. due to self-induction) which continues the current in the same direction across the gap to recharge the condenser. It is important to notice at this moment that the condenser's polarity is reversed and the charge in it is of much lesser magnitude than the initial charge principally because of the great heat loss or dissipation at the gap. These functions complete an alternation of radio-frequency current. The next alternation of r.f. begins when the condenser discharges and sends current in the opposite direction across the gap and through the inductance again setting up magnetic lines which in turn generate a voltage (e.m.f. due to self-induction); hence, the current continues to flow to the condenser to recharge it. At the end of this alternation we find that the condenser is recharged, with its polarity again reversed and the charge in it greatly reduced compared with the previous charge because of the high dissipation at the gap. The circuit functions just given complete a cycle of radio-frequency current, called an *oscillation.*

These functions are common to other oscillatory circuits in so far as concerns the production of oscillations (so-called flywheel effect) and the difference mainly is due to the presence of the gap in series with the oscillatory system. It takes a high voltage to break down the gap's resistance, and the dissipation (in heat at the gap) with each passage of current is enormous when compared with the dissipation in an ordinary oscillatory system where the inductance and capacitance are connected together without such a gap. For these reasons the amplitudes of successive alternations are rapidly reduced with a wide gap and therefore only a comparatively few oscillations, sometimes only 25 or more in highly damped circuits, are generated before they die out, or damp out. A damped wave, therefore, is composed of successive series of oscillations in which the amplitude after attaining a maximum decreases gradually. The frequency of the oscillations depends upon the L and C values and somewhat on the R value, which is represented principally in the gap. Another group of similarly damped oscillations will be generated on the next alternation of the power cycle when the condenser is charged to a voltage that will again break down the resistance of the gap.

3.147. *Question.* Explain the "negative resistance" characteristic of an oscillating arc circuit.

Answer. An arc oscillator depends upon current conduction by means of a gas where ionization enters into the action. A current passing through a gas causes ionization, which produces ions and makes the path more conductive, thus permitting more current to flow which would cause further ionization, and, therefore, in effect the resistance of the arc becomes less as the current increases. Of course, limitations which control this rise of current are the regulation of the power supply and the point at which saturation of the gas occurs. This characteristic, called *negative resistance,* is contrary to Ohm's law because in this action an increase and decrease of current results in a corresponding decrease and increase of voltage drop across the electrodes of the arc. Ohm's law is based upon a "positive resistance" characteristic, or one relating to current conduction in solids, or metals, which dissipates energy in the circuit; according to Ohm's law an increase and decrease of current through a given resistance results in a proportional increase and decrease of the voltage drop across the resistance. When d-c power is applied to the arc the oscillatory circuit receives an impulse which starts it oscillating because the negative resistance arc is in series with and balances the positive resistance of the oscillatory system; it is the positive resistance in an oscillatory system that stops oscillation.

3.148. *Question.* List the characteristics of a dynatron type of oscillator.

Answer. The characteristics of a dynatron oscillator are excellent frequency stability, low output, and low efficiency. The dynatron oscillator is useful as a reference and for calibration purposes in an instrument such as a heterodyne frequency meter. Its use in general is restricted because of the low output.

3.149. *Question.* List the characteristics of an electron-coupled type of oscillator.

Answer. The characteristics of an electron-coupled oscillator are excellent frequency stability and medium power output. This type is very stable because the oscillator section of the tube is coupled into the load only by the electron flow from cathode to plate in the tube and therefore changes in plate circuit load impedance have practically no effect on the tuned circuit constants.

3.150. *Question.* Upon what characteristics of an electron tube does a dynatron type of oscillator depend?

Answer. A dynatron oscillator depends upon secondary emission, which gives the tube a negative resistance characteristic. The operation of this oscillator requires the screen grid to be adjusted at about twice the plate voltage so that the electrons (secondary electrons) lost to the plate go to the higher positive potential grid. This gives the tube a negative resistance characteristic because increases of plate voltage decrease the plate current, whereas decreases of plate voltage reduce the secondary emission effect, which increases the plate current. The oscillator circuit, being a positive resistance and connected in the plate circuit, is in effect shunted across the negative resistance tube. When the negative and positive resistances balance, making the net resistance zero, then oscillations start; and for a greater negative resistance the amplitude of the oscillations builds up accordingly.

3.151. *Question.* What is a multivibrator and what are its uses?

Answer. A multivibrator is an oscillator consisting of a two-stage resistance-coupled amplifier with the output feeding back into the input. The frequency depends upon the R and C values of the interstage coupling elements; the 180° phase shift in each tube provides the correct regeneration voltage on the grid of the input tube. A multivibrator is a form of relaxation oscillator which has the unique property of being readily stabilized and controlled by a frequency from another source, which may be introduced into its control circuit, usually in the grid return of the second tube. If the control frequency, or trigger frequency, is slightly higher than the fundamental of the multivibrator it falls in step and generates submultiples, or subharmonics, of the control frequency. For example, a multivibrator will generate 10-kilocycle harmonics from a control frequency of 100 kilocycles supplied by a separate oscillator, and 1-kilocycle harmonics from a 10-kilocycle oscillator or other multivibrator. Hence, a multivibrator is essentially a frequency divider, which makes it very useful as a reference in standard frequency equipment.

3.152. *Question.* If a frequency meter having an over-all error proportional to the frequency is accurate to 10 cycles when set at 600 kilocycles, what is its error in cycles when set at 1,110 kilocycles?

Answer. The error is 18.5 cycles.

Computation: The error in cycles is proportional to the frequency in kilocycles, therefore

$$10 : 600 :: X : 1{,}110$$

and since the product of the means equals the product of the extremes, we have

$$600X = 10 \times 1{,}110$$

or

$$X = 18.5 \text{ cycles}$$

3.153. *Question.* What precautions should be taken before using a heterodyne type of frequency meter?

Answer. A heterodyne-frequency meter should be allowed to warm up thoroughly before it is used. Also, the operating voltages should be normal, and just before it is used the meter should be put in calibration by adjusting it to zero beat. Furthermore, only a pure d.c. should be used for plate supply, and the meter should be periodically checked against a calibrated frequency oscillator.

3.154. *Question.* **What is the meaning of "zero beat" as used in connection with frequency measuring equipment?**

Answer. Zero beat is a condition wherein two frequencies are in exact agreement, and therefore there is no heterodyning action between them.

Since the frequency of the oscillator of the frequency meter can be read on a calibrated dial by first beating the meter to zero to place it in calibration then the frequency being measured can also be read on the dial at zero beat.

3.155. *Question.* **What precautions should be observed by using an absorption-type frequency meter to measure the frequency of a self-excited oscillator? Explain your reasons.**

Answer. The coupling between the meter pick-up coil and the oscillator should be as loose as practicable to give just a readable indication. The reactions between coupled circuits affect the frequency so that coupling closer than necessary only tends to detune the oscillator and cause error in the reading.

3.156. *Question.* **If the first speech amplifier tube of a radiotelephone transmitter were overexcited but the percentage modulation capabilities of the transmitter were not exceeded, what would be the effect upon the output of the transmitter?**

Answer. Overexcitation in the first amplifier tube would result in severe distortion through the audio stages and in the modulator output which would then be carried to the modulated r-f amplifier, thus causing the audio distortion to be present in the output wave.

3.157. *Question.* **What is the purpose of a "preamplifier"?**

Answer. A preamplifier is used to raise the speech level at the source in order to provide adequate excitation for a regular amplifier located some distance away. For example, a condenser microphone has a low output and requires a small preamplifier to be mounted within the head, or housing, as a component part. The noise-to-signal ratio is improved by a preamplifier which amplifies a signal at its source before transmitting it in a line which might pick up interference or noise.

3.158. *Question.* **What are the advantages of using two tubes in push-pull as compared with the use of the same tubes in parallel in an audio-frequency amplifier?**

Answer. Distortion is reduced to a minimum by push-pull operation as suggested by the following advantages:

(*a*) Second harmonic component is effectively balanced out.

(*b*) Prevention of core saturation of the output transformer.

> In push-pull the plate d-c component flows in opposite directions through each half of the primary and, consequently, no flux will be set up with equal values of d.c. in each plate circuit. Only the a-c component is required to produce flux changes which pass the signal to the secondary.

(*c*) Equalization of the output of each tube is obtained with push-pull, when excitation is applied.

> This equalizing of the two plate currents is obtained when a cathode bias resistor is used without a bypass condenser, because under such conditions of operation the

output of each tube (voltage obtained across the resistor applied to each grid) has a degenerating effect on itself but a regenerating effect on the other tube.

(*d*) Reduced hum ripple component with equivalent filter systems; that is, less filtering of the power supply is necessary for a given permissible hum level than would be the case with tubes operated in parallel.

(*e*) Greater undistorted power output.

3.159. ***Question.*** List four causes of distortion in a class A audio-frequency amplifier.

Answer. Distortion in a class A audio amplifier may be caused by any of the following: (1) Improper grid bias; (2) feedback, or regeneration in the amplifier; (3) improper load impedance; (4) overdriving the grid, that is, excessive excitation voltage.

3.160. *Question.* What is the purpose of a bypass condenser connected across an audio-frequency amplifier cathode bias resistor?

Answer. A bypass condenser across the cathode bias resistor of an a-f amplifier serves as a low impedance path for the audio component, which results in a better low frequency response and prevents degeneration effects which reduce the gain. Otherwise, or without the bypass condenser, a single ended audio stage would have to be designed to provide a greater gain to offset the effects of degeneration.

3.161. *Question.* What are the advantages of using a resistor in series with the cathode of a class C radio-frequency amplifier tube to provide bias?

Answer. The use of a cathode bias resistor in a class C amplifier is a protective measure against the plate current rising excessively with possible damage to the tube in case the grid suddenly lost its normal bias for any reason. The plate current flowing through the resistor supplies approximately cutoff bias which holds the plate current down to a safe value if the normal bias were removed. Loss of bias might be caused through failure of a separate bias supply, or if grid-leak biasing were used the bias would be removed if excitation were interrupted or accidently stopped.

3.162. *Question.* How may the generation of even harmonic energy in a radio-frequency amplifier stage be minimized?

Answer. The generation of even harmonic energy in an r-f stage may be minimized by operating the stage in push-pull with matched tubes and by the use of a Faraday screen.

3.163. *Question.* What tests will determine if a radio-frequency power amplifier stage is properly neutralized?

Answer. Neutralization of an r-f amplifier may be checked (1) by tuning the plate tank circuit back and forth through resonance sufficiently to note that the grid d-c meter does not fluctuate but gives a steady reading since the grid current passing through a smooth peak indicates proper neutralization, (2) by removing the plate voltage with excitation applied and coupling a suitable r-f indicator to the plate tank circuit which will show no r.f. or minimum r.f. when properly neutralized, and (3) by excessive plate current, which might indicate an unneutralized condition.

3.164. *Question.* Why is the plate circuit efficiency of a radio-frequency amplifier tube operating as class C higher than that of the same tube oper-

ated as class B? If the statement above is false, explain your reasons for such a conclusion.

Answer. The statement is true. In the operation of an r-f amplifier the smaller the angle of flow of plate current during the excitation cycle the higher will be the efficiency. In class C operation the grid bias is adjusted to a value well beyond cutoff so that the plate current flows for much less than 180° of the excitation cycle, whereas, in class B the bias is adjusted approximately at cutoff and plate current flows for at least 180° of the excitation cycle.

3.165. *Question.* **Why does a class B audio-frequency amplifier stage require considerably greater driving power than a class A audio amplifier?**

Answer. The grid is biased at the cutoff point and a grid swing of large amplitude is necessary to drive the plate current sufficiently high on the characteristic to obtain linear operation. In addition, a class B operated tube draws grid current which is a loss of power in the grid circuit, which must be supplied by the driver stage.

3.166. *Question.* **Discuss the input circuit requirements for a class B audio-frequency amplifier grid circuit.**

Answer. Important requirements in the operation of a class B audio stage are a low impedance input circuit and excellent voltage regulation of the driver stage. These conditions should be satisfied because during the time the grids draw current the voltage drop across the grid circuit impedance lowers the amplitude of the signal voltage and thus distorts the wave form. Also, the driver stage should have very good regulation because the losses in the grid circuit take considerable power which must be supplied by the driver stage. In practice a step-down ratio is used in the coupling transformer between the driver and the class B stage.

3.167. *Question.* **When a signal is impressed on the grid of a properly adjusted and operated class A audio-frequency amplifier, what change in average value of plate current will take place?**

Answer. The average value of the plate current remains unchanged.

3.168. *Question.* **If the value of capacitance of a coupling condenser in a resistance coupled audio amplifier is increased, what effect may be noted?**

Answer. A coupling condenser of a higher capacitance will improve the low frequency response of the amplifier. However, if the capacitance is increased too much it may cause certain undesirable effects such as motor-boating resulting from the change in time period of the grid circuit, which depends upon the R and C values.

3.169. *Question.* **Why does a screen grid tube normally require no neutralization when used as a radio-frequency amplifier?**

Answer. The capacitive coupling between the plate and control grid in the tube is reduced to such a negligible value by the presence of the screen grid that normally there is not sufficient feedback to cause oscillation.

3.170. *Question.* **What instruments or devices may be used to adjust and determine that an amplifier stage is properly neutralized?**

Answer. A simple form of a radio-frequency indicator is a small loop of wire, or a small pick-up coil, connected in series with an r-f meter of the thermocouple type. However, instead of an r-f meter the indicator could be a neon bulb, or a flashlight lamp. A more sensitive type of indicator consists of the small pick-up coil connected to a vacuum tube detector with a d-c milliammeter in the plate circuit for the indicator. The simpler forms of indicators absorb more r.f. and therefore require closer coupling to the plate circuit of the amplifier than would be necessary when a detector tube and milliammeter with the pick-up coil is used. A grid current meter could be used to check for proper neutralization.

3.171. ***Question.*** **What is meant by the term "unity coupling"?**

Answer. "Unity coupling" between a primary and its secondary winding is the condition in which all the flux produced by the primary links with the secondary turns.

3.172. ***Question.*** **Draw a diagram illustrating "capacitive" coupling between two tuned radio-frequency circuits.**

Answer. See Figure 61.

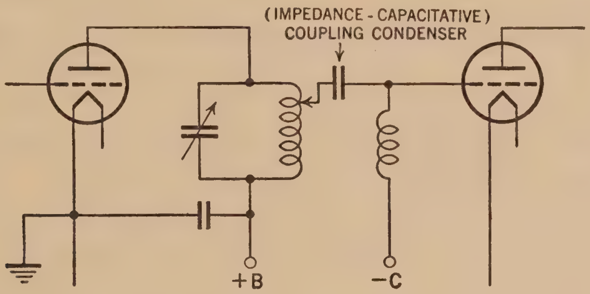


FIG. 61. Example of capacitive coupling between r-f stages.

3.173. ***Question.*** **Draw a diagram illustrating "inductive" coupling between two tuned radio-frequency circuits.**

Answer. See Figure 62.

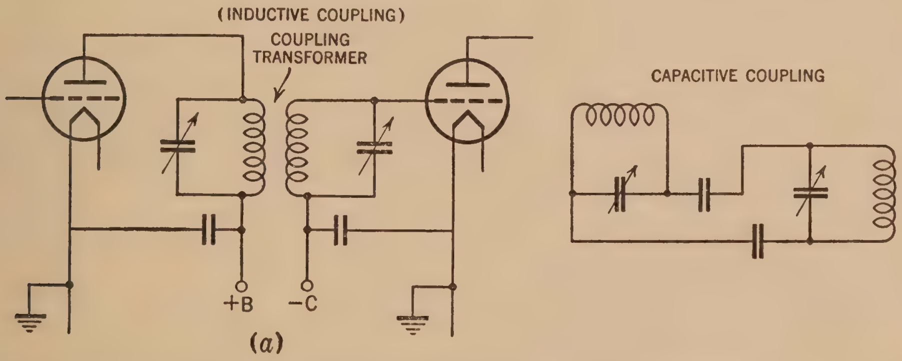
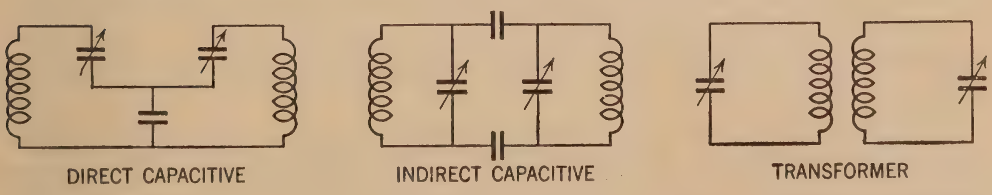


FIG. 62*a*. Two types of coupling, inductive and capacitive.



DIRECT CAPACITIVE

INDIRECT CAPACITIVE

TRANSFORMER

FIG. 62*b*. Three types of coupling, namely, direct capacitive, indirect capacitive, and inductive or transformer.

3.174. ***Question.*** **Draw a diagram illustrating "direct" or "Loftin-White" coupling between two stages of audio-frequency amplification.**

Answer. See Figure 63.

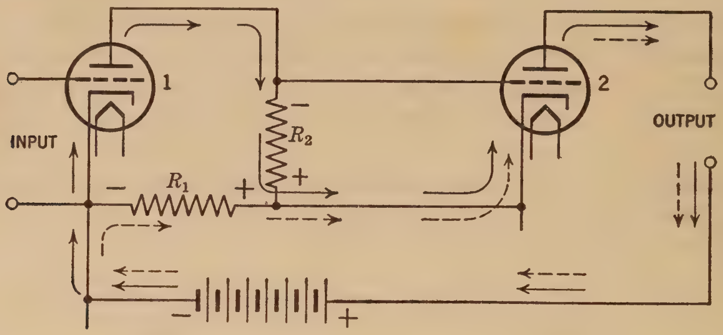


FIG. 63. Loftin-White amplifier, basic circuit.

3.175. ***Question.*** **List four classes of stations which may be operated by a person holding a radiotelephone second-class license.**

Answer. Any station while using type AO, A3, A4, or A5 emission except standard broadcast stations, international broadcast stations, or ship stations licensed to use power in excess of 100 watts and type A3 emission for communication with coastal telephone stations. Four classes of stations which may be included in the foregoing rule for which a radiotelephone second-class license is valid are as follows:

1. Relay broadcast stations.
2. Television broadcast stations.
3. Experimental stations.
4. Aeronautical stations provided A1 or A2 emission is not used.

(F.C.C. Rules and Regulations 13.61.)

3.176. ***Question.*** **List four classes of broadcast stations which may be operated by the holder of a radiotelephone second-class operator license.**

Answer. A radiotelephone second-class operator license is valid for operation of the following broadcast stations:

1. Relay broadcast stations.
2. Television broadcast stations.
3. Facsimile broadcast stations.
4. Experimental broadcast stations.

3.177. ***Question.*** **May the holder of a radiotelephone second-class operator license adjust and service or supervise the adjustment and servicing of any class of police radio station?**

Answer. Yes, any class of police radio station except stations using A1 or A2 emission.

3.178. ***Question.*** **List four classes of stations, the equipment of which may be adjusted and serviced by the holder of a radiotelephone second-class operator license.**

Answer. The stations which may be adjusted and serviced by the holder of a radiotelephone second-class operator license include the following:

1. Relay broadcast stations.
2. Television broadcast stations.
3. Facsimile broadcast stations.
4. Experimental broadcast stations.

3.179. ***Question.*** **List three classes of stations which may not be serviced or adjusted by the holder of a radiotelephone second-class operator license.**

Answer. In accordance with the F.C.C. Rules and Regulations 13.61, three classes of stations are as follows:

1. Standard broadcast stations.
2. International broadcast stations.
3. Ship stations licensed to use power in excess of 100 watts and A3 emission for communication with coastal telephone stations.

3.180. ***Question.*** **If an operator is employed at more than one station, how may the requirements of the Commission's Rules and Regulations be met with respect to the posting of operator licenses?**

Answer. The holder of a radiotelegraph or radiotelephone first- or second-class license who is employed as a service and maintenance operator at stations operated by holders of Restricted Operator Permits shall post at such stations his operator license or a verified statement from the Commission in lieu thereof. (F.C.C. Rules and Regulations 13.75.)

3.181. ***Question.*** **Is it necessary that the original operator license be posted at an aeronautical station? An aircraft station? An airport station? A broadcast station? A ship station?**

Answer. The operator's license must be posted during the time the operator is on duty at aeronautical, airport, broadcast, and ship stations. At aircraft stations, either the operator's license or form 752F must be on the operator's person at all times while on duty.

3.182. ***Question.*** **What is a "verification card," and under what circumstances may it be used?**

Answer. The holder of an operator license who operates any station in which the posting of an operator license is not required may, upon filing application in duplicate accompanied by his license, obtain a verification card. This card may be carried on the person of the operator in lieu of the original operator license, provided that the license is readily accessible within a reasonable time for inspection upon demand by an authorized government representative.

3.183. ***Question.*** **If a ship-telephone station is assigned the frequency of 2,738 kilocycles and the maximum tolerance is 0.04 per cent, what are the highest and lowest frequencies within the tolerance limits?**

Answer. The frequency tolerance range is between 2,739.0952 and 2,736.9048 kilocycles.

Computation: Given a tolerance of 0.04 per cent and an assigned frequency of 2,738 kilocycles means that the frequency is permitted to vary above and below the assigned frequency by 1.0952 kilocycles, which is found by multiplying 0.0004 by 2,738.

3.184. ***Question.*** **If an aircraft station is assigned the frequency of 3,105 kilocycles and the maximum tolerance is 0.1 per cent, what are the highest and lowest frequencies within the tolerance limits?**

Answer. The highest and lowest frequencies within the tolerance limits are 3,108.105 kilocycles and 3,101.895 kilocycles, respectively.

Computation: A maximum tolerance of 0.1 per cent means that the frequency has a range on either side of the assigned frequency of 0.001 × 3,105, or 3.105 kilocycles.

3.185. ***Question.*** **If a heterodyne frequency meter having a calibrated range of 1,000 to 5,000 kilocycles is used to measure the frequency of a transmitter operating on approximately 500 kilocycles by measurement of the second harmonic of this transmitter and the indicated measurement is 1,008 kilocycles, what is the actual frequency of the transmitter output?**

Answer. 504 kilocycles. A second harmonic of 1,008 kilocycles gives a fundamental of 504 kilocycles.

3.186. ***Question.*** **Under what conditions may a log *not* be maintained by a radio station in the aviation or emergency service?**

Answer. All stations in the aviation service *except aircraft stations* must keep an adequate log showing (1) hours of operation, (2) frequencies used, (3) stations with which communication was held, and (4) signature of operator(s) on duty. (F.C.C. Rules and Regulations 9.41.) In accordance with the rules a log need not be kept during an emergency but immediately after the emergency the log should be made out and verified by an authorized operator present during the emergency. An aircraft station not in the public service is not required to keep a log at any time.

3.187. ***Question.*** **What information must be entered in the radio station log of an aircraft station not open to public service?**

Answer. An aircraft station not open to public service is not required to keep a log in accordance with F.C.C. Rule 9.41.

Note. However, aircraft stations in the public service must keep a log showing (1) hours of operation, (2) frequencies used, (3) stations with which communication was held, and (4) signature of operator(s) on duty, the foregoing being in accordance with F.C.C. Rule 9.42.

3.188. ***Question.*** **List four entries required to be entered in the radio station log of a station in the aviation service.**

Answer. All stations in the aviation service except aircraft stations must keep an adequate log showing (1) hours of operation, (2) frequencies used, (3) stations with which communication was held, and (4) signature of operator(s) on duty. (F.C.C. Rules and Regulations 9.41.)

3.189. ***Question.*** **List four entries required to be entered in the radio station log of a station in the emergency service.**

Answer. The rules governing emergency radio services state that each licensee shall maintain adequate records of the operation of the station, including (1) hours of operation; (2) nature and time of each transmission; (3) name of operator on duty at the transmitter. (F.C.C. Rules and Regulations 10.101.)

Note. It is seen that the foregoing rule mentions four entries, namely, (1) hours of operation; (2) nature of each transmission; (3) time of each transmission; (4) name of operator on duty.

3.190. ***Question.*** **Define the following types of emission: A0, A1, A2, A3, A4, A5.**

Answer. The emissions classified as continuous waves, or type A, are as follows:

Type A0.	Waves the successive oscillations of which are identical under fixed conditions.
Type A1.	Telegraphy on pure continuous waves. A continuous wave which is keyed according to a telegraph code.
Type A2.	Modulated telegraphy. A carrier wave modulated at one or more audible frequencies; the audible frequency or frequencies or their combination with the carrier wave being keyed according to a telegraph code.
Type A3.	Telephony. Waves resulting from the modulation of a carrier wave by frequencies corresponding to the voice, to music, or to other sounds.
Type A4.	Facsimile. Waves resulting from the modulation of a carrier wave by frequencies produced at the time of the scanning of a fixed image with a view to its reproduction in a permanent form.
Type A5.	Television. Waves resulting from the modulation of a carrier wave by frequencies produced at the time of the scanning of fixed or moving objects.

Note. The following defines damped waves, or Type B waves: Waves composed of successive series of oscillations the amplitudes of which, after attaining a maximum, decrease gradually, the wave trains being keyed according to a telegraph code.

3.191. ***Question.*** **What is the radiotelephone distress signal?**

Answer. In radiotelephony, the distress signal consists of the spoken expression MAYDAY (corresponding to the French pronunciation of the expression *m'aider*).

3.192. ***Question.*** **What is the radiotelephone safety signal?**

Answer. In radiotelephony, the word SECURITY (corresponding to the French pronunciation of the word *sécurité*), repeated three times, shall be used as the safety signal.

3.193. ***Question.*** **What is indicated if the signal SECURITY is intercepted?**

Answer. The safety signal SECURITY announces that the calling station is about to transmit a message concerning the safety of navigation or giving important meteorological warnings.

3.194. ***Question.*** **What is indicated if the signal PAN is intercepted?**

Answer. The urgent signal PAN shall indicate that the calling station has a very urgent message to transmit concerning the safety of a ship, an aircraft, or another vehicle, or concerning the safety of some person on board or sighted from on board.

In the aeronautical service, the urgent signal PAN shall be used both in radiotelegraphy and in radiotelephony to indicate that the aircraft transmitting it is in trouble and is forced to land, but that it is not in need of immediate help. This signal should, so far as possible, be followed by a message giving additional information.

3.195. ***Question.*** **If an operator should intercept the signal PAN transmitted by radiotelephony, what would he do?**

Answer. The urgent signal PAN shall have priority over all other communications, except distress communications, and all mobile or land stations hearing it must take care not to interfere with the transmission of the message which follows this signal.

3.196. ***Question.*** **What are the circumstances under which the safety signal should be transmitted by radiotelephony?**

Answer. The safety signal SECURITY announces that the calling station is about to transmit a message concerning the safety of navigation or giving important meteorological warnings.

3.197. ***Question.*** **In the adjustment of a radiotelephone transmitter, what precautions should be observed?**

Answer. The precautions to observe in the adjustment of a radiotelephone transmitter have to do mainly with matters concerning interference with other stations, the correct frequency of emission, the use of excessive power, and overmodulation. In the adjustment of the transmitter make sure that each test emission will not interfere with the services of other stations. It is important that the transmitter comply in every way with the terms of the station license or permit which includes operating only on the assigned frequency and according to the power specified. Also, the amount of harmonic radiation and percentage of modulation should conform to the rules and regulations covering the type of transmitter and service involved.

3.198. ***Question.*** **Which classes of stations have no power limitations prescribed by the Commission?**

Answer. Stations having no power limitations prescribed by the Commission are aircraft stations in general and fixed municipal and state police stations operting on certain frequencies.

3.199. ***Question.*** **If an operator should willfully and maliciously interfere with any radio communications or signals other than distress, what penalties should he be subject to?**

Answer. Any person who willfully and knowingly violates any rule, regulation, restriction, or condition made or imposed by the Commission under authority of the Communications Act, or any rule, regulation, restriction, or condition made or imposed by any international radio or wire communications treaty or convention, or regulations annexed thereto, to which the United States is or may hereafter become a party, shall, in addition to any other penalties provided by law, be punished, upon conviction thereof, by a fine of not more than $500 for each and every day during which such offense occurs. (Communications Act of 1934, as amended, Section 502.)

3.200. ***Question.*** **Under what circumstances may messages concerning the detection or prevention of crime be exchanged by radiotelephone between municipal and police radio stations?**

Answer. Municipal police stations, although licensed primarily for communication with mobile police units, may transmit emergency messages to other mobile units such as fire department vehicles, private ambulances, and repair units of public utilities in those cases which require cooperation or coordination with police activities. In addition, such stations may communicate among themselves provided (1) that no interference is caused to the mobile service, and (2) that communication is limited to places between which, by reason of their close proximity, the use of radiotelegraph stations is impracticable. Municipal police stations shall not engage in point-to-point radio communication beyond the good service range of the transmitting station or transmit or handle communications requiring radiotelephone relay. Point-to-point communication between stations in the same local telephone exchange area is likewise prohibited unless messages to be transmitted are of immediate importance to mobile units. (F.C.C. Rules and Regulations 10.126.)

3.201. *Question.* What is the meaning of "a station open to public service"?

Answer. A station open to public service is a station which handles public correspondence, paid or toll messages, or provides radiotelephone facilities for the use of the general public.

3.202. *Question.* Under what circumstances may an aircraft radio station call an airport station on 3,105 kilocycles?

Answer. The use of 3,105 kilocycles is restricted to communications pertaining solely to aircraft operation and the protection of life and property. This frequency is a national and international aircraft calling and working frequency primarily for use by nonscheduled, or itinerant, aircraft. Contacts with airport control stations shall under normal circumstances not be attempted unless the aircraft is within the control area of the airport, an area approximately within 30 miles or 10 minutes' flight of the airport.

3.203. *Question.* If, upon being called by another station, a called station is unable to proceed with the acceptance of traffic without a slight delay, what procedure should be adopted by the operator?

Answer. If the station called is prevented from receiving, it shall reply to the call as indicated in the General Radio Regulations, but it shall replace the letter *K* by the signal ·—··· (wait), followed by a number indicating in minutes the probable duration of the wait. If this probable duration exceeds 10 minutes (5 minutes in the aeronautical mobile service), a reason must be given therefor.

3.204. *Question.* To what aircraft is an aeronautical station required to provide nonpublic service?

Answer. Aeronautical stations shall provide nonpublic service without discrimination to all scheduled aircraft the owners of which make cooperative arrangements for the operation and maintenance of the aeronautical stations which are to furnish such service and for shared liability in the operation of stations. In addition, this class of station shall provide reasonable and fair service to nonscheduled aircraft in accordance with the provisions of these rules. (F.C.C. Rules and Regulations, 9.101.)

3.205. *Question.* Is an aeronautical station permitted to transmit messages?

Answer. Yes, an aeronautical station is permitted to transmit messages pertaining to aircraft operation and the protection of life and property. Authorized messages over aeronautical station circuits are as follows:

1. Communications with aircraft.
2. Weather.
3. Operations pertaining to aircraft in flight.
4. Messages relating to aircraft loads.
5. Any emergency message relating to aircraft operation not specified above.
6. Unscheduled communication with other stations in the aviation service when necessary.

3.206. *Question.* In what kind of communications may an experimental station engage?

Answer. An experimental station shall not be used to conduct general message traffic of any kind, to demonstrate equipment for prospective sales purposes, to transmit programs for direct entertainment, to transmit the programs of any other station, except in conjunction with experimental programs, or to render any commercial communication service or communications involving advertising, either directly or indirectly, subject to specific limitations and restrictions which will be prescribed in individual cases by the Commission. This authority will be granted only for special reasons to obtain information or data which give promise of being of benefit to the radio art.

3.207. *Question.* Under what circumstances will remote control of a radio transmitter, other than broadcast, with the operator at a point other than the location of the transmitter, be authorized by the Commission?

Answer. An operator or operators may be on duty at the control station in lieu of the place where the transmitting apparatus is located subject to the following conditions:

1. The transmitter shall be capable of operation and shall be operated in accordance with the terms of the station license.
2. The transmitter shall be so located and housed that it is not accessible to other than duly authorized persons.
3. The emissions of the transmitter shall be continuously monitored at the control point by a licensed operator of the grade specified for the class of station involved.
4. Proper apparatus and methods shall be provided so that the transmitter can quickly and without delay be placed in an inoperative condition, in the event there is a deviation from the terms of the station license.
5. The radiation of the transmitter shall be suspended immediately when there is a deviation from the terms of the station license. (F.C.C. Rules and Regulations 2.53.)

3.208. *Question.* Under what circumstances may aircraft equipment be tested in flight?

Answer. The licensees of all classes of stations in the aviation service are authorized to make such routine tests as may be required for the proper maintenance of the station provided that precautions are taken to avoid interference with any station. Tests on 3,105 and 6,210 kilocycles using a regular antenna system can be made only at such times as no interference will be caused and, if in the range of an airport control station or Civil Aeronautics Authority station, only after permission is secured from such stations before commencing the tests. (F.C.C. Rules and Regulations 9.32.)

3.209. *Question.* At all broadcast stations for which a second-class radiotelephone license is valid, how often must the frequency of emission be checked?

Answer. The frequency of these stations shall be checked at each time of beginning operation and as often thereafter as necessary to maintain the frequency within the allowed tolerance. (F.C.C. Rules and Regulations 4.2.)

3.210. *Question.* Explain the relation between the signal frequency, the oscillator frequency, and the image frequency in a superheterodyne receiver.

Answer. The image frequency and the signal frequency are an equal number of kilocycles on opposite sides from the oscillator frequency. If the image frequency is above the oscillator frequency the signal frequency is an equal distance below, or it may be the other way around, where the signal frequency is above and the image frequency below the oscillator frequency. Therefore, either the difference between the image frequency and the oscillator frequency or the difference between the signal frequency and the oscillator frequency will give the same intermediate frequency. The frequency separation between the image and signal frequencies is equal to twice the intermediate frequency.

3.211. *Question.* What means are used to prevent interaction between the stages of a multistage audio-frequency amplifier?

Answer. Plate isolation and shielding are used to prevent interaction between the stages of a multistage audio-frequency amplifier. Plate isolation is accomplished by using *R-C* filters consisting of resistors, properly bypassed, connected in each plate supply lead, which prevent coupling through the internal impedance of a common *B* supply. If necessary, decoupling filters are used in grid supply leads. Shielding prevents magnetic and electrostatic coupling directly between stages. Also, the physical placement of the component parts for minimum reaction between them is another consideration.

3.212. *Question.* Under what conditions, if any, may a station be operated by an unlicensed person or by an operator not holding a license of the grade normally required for that station?

Answer. The actual operation of all transmitting apparatus in any licensed radio station shall be carried on only by a person holding an operator's license in such station. However, it is provided that the Commission, if it shall find that the public interest, convenience, or necessity will be served thereby, may waive or modify the foregoing provisions for the operation of any station except (1) stations for which licensed operators are required by international agreement, (2) stations for which licensed operators are required for safety purposes, (3) stations engaged in broadcasting, and (4) stations operated as common carriers on frequencies below 30,000 kilocycles. Further provisions give the Commission power to make special regulations governing the granting of licenses for the use of automatic radio devices and for the operation of such devices. (Communications Act of 1934, as amended, Sec. 318.)

3.213. ***Question.*** **For what period of time must a log containing distress entries be retained?**

Answer. Logs containing communications incident to a disaster, or which include communications incident to or involved in an investigation by the Commission and concerning which the licensee has been notified, shall be retained by the licensee until specifically authorized in writing by the Commission to destroy them. (F.C.C. General Rules and Regulations 2.54.)

ELEMENT 4

ADVANCED RADIOTELEPHONE

4.1. ***Question.*** **A parallel circuit is made up of five branches, three of the branches being pure resistances of 7, 11, and 14 ohms. The fourth branch has an inductive reactance value of 500 ohms. The fifth branch has a capacitive reactance of 900 ohms. What is the total impedance of this network? If a voltage is impressed across this network, which branch will dissipate the greatest amount of heat?**

Answer. The total impedance is 3.28 ohms and the 7-ohm branch will dissipate the greatest amount of heat.

Solution: The total (or equivalent) impedance of the circuit in terms of admittance, susceptance, and conductance is expressed by this formula:

$$Z = \frac{1}{y_0} = \frac{1}{\sqrt{g_0^2 + b_0^2}},$$

where g_0 = total conductance,
b_0 = total susceptance,
y_0 = total admittance,
Z = total (or equivalent) impedance.

The total conductance equals the sum of the separate conductances, or

$$g_0 = g_1 + g_2 + g_3 + g_4 + g_5$$

$$= \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_2} + 0 + 0$$

(Branches 4 and 5 are pure reactances and hence have no conductance.)

$$b_0 = b_1 + b_2 + b_3 + b_4 + b_5$$

$$= 0 + 0 + 0 + \frac{1}{X_4} + \frac{1}{X_5}$$

(Branches 1, 2, and 3 are pure resistances and hence have no susceptance.)

Problem 1. This problem is solved by applying the above formulas as follows: (See Figure 64.)

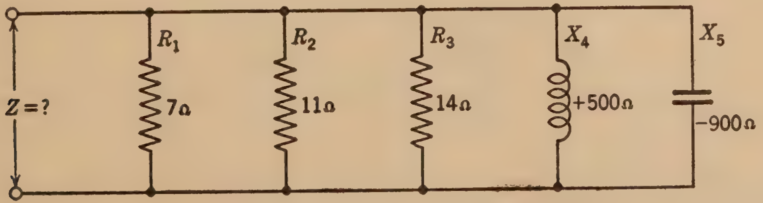


FIG. 64. Problem in a-c circuit theory.

$$g_0 = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{7} + \frac{1}{11} + \frac{1}{14} = 0.143 + 0.091 + 0.071 = 0.305$$

$$b_0 = \frac{1}{X_4} + \frac{1}{X_5} = \frac{1}{500} - \frac{1}{900} = 0.00200 - 0.00111 = 0.00089$$

$$y_0 = \sqrt{g_0^2 + b_0^2} = \sqrt{(0.305)^2 + (0.00089)^2} = 0.305$$

$$Z = \frac{1}{y_0} = \frac{1}{0.305} = 3.28 \text{ ohms}$$

Problem 2. Power is dissipated only in the resistive portion of an impedance and is always given by

$$P = I^2R, \quad \text{where } R = \text{a-c resistance,} \quad I = \text{current.}$$

In cases where there is no reactance, that is, where the element is a pure resistance, the power is also given by

$$P = \frac{E^2}{R}, \quad \text{or} \quad P = EI, \quad \text{where } E = \text{voltage across resistance } R, \quad I = \text{current through resistance } R.$$

There is no power dissipated in the reactive branches, so by applying the power formula with the voltage, E, the same across all branches the power for each resistance may be worked out individually. It will be greatest in the branch which has the smallest resistance, or the 7-ohm branch.

4.2. *Question.* What is the reactance of a condenser at the frequency of 1,200 kilocycles if its reactance is 300 ohms at 680 kilocycles?

Answer. 170 ohms is the reactance of the condenser.

Solution: Before working out the specific problem we will set down the reasoning which enables us to express the reactance of the condenser at the new frequency.

Let X_1 = reactance of condenser at f_1
X_2 = reactance of condenser at f_2

Then $X_1 = \dfrac{1}{2\pi f_1 C}$ and $X_2 = \dfrac{1}{2\pi f_2 C}$ (numerically). The relation of the two reactances and the two frequencies is

$$\frac{X_2}{X_1} = \frac{\dfrac{1}{2\pi f_2 C}}{\dfrac{1}{2\pi f_1 C}} = \frac{1}{2\pi f_2 C} \times \frac{2\pi f_1 C}{1} = \frac{f_1}{f_2}$$

Since $\dfrac{X_2}{X_1} = \dfrac{f_1}{f_2}$, then $X_2 = \dfrac{f_1}{f_2} X_1$.

In the given problem:

$$f_2 = 1{,}200 \text{ kc}, \qquad f_1 = 680 \text{ kc}, \qquad \text{and } X_1 = 300 \text{ ohms (capacitive ohms)}$$

whence $X_2 = \dfrac{680}{1{,}200} \times 300 = 170$ ohms (capacitive).

Note. It can readily be shown also that if the *inductive reactance* of a coil were to be found at another (new) frequency the same reasoning would apply, as follows:

If X_1 = reactance of a coil at f_1 (original frequency) and X_2 = reactance of a coil at f_2 (new frequency), then $\dfrac{X_2}{X_1} = \dfrac{f_2}{f_1}$, or $X_2 = \dfrac{f_2}{f_1} X_1$.

4.3. *Question.* If the mutual inductance between two coils is 0.1 henry and the coils have inductances of 0.2 and 0.8 henry, respectively, what is the coefficient of coupling?

Answer. The coefficient of coupling is 0.25.

Solution: The formula for mutual inductance is

$M = K\sqrt{L_1 L_2}$, where L_1 and L_2 are the two inductances
M is mutual inductance
K is coefficient of coupling

Solving for K:

$$K = \frac{M}{\sqrt{L_1 L_2}}$$

In the problem the values of M, L_1, and L_2 are given; hence

$$K = \frac{M}{\sqrt{L_1 L_2}} = \frac{0.1}{\sqrt{0.2 \times 0.8}} = \frac{0.1}{\sqrt{0.16}} = \frac{0.1}{0.4} = 0.25, \text{ coefficient of coupling}$$

4.4. *Question.* If, in a given a-c series circuit, the resistance, inductive reactance, and capacitive reactance are equal magnitudes of 11 ohms, and the frequency is reduced to 0.411 of its value at resonance, what is the resultant impedance of the circuit at the new frequency?

Answer. 24.8 ohms.

Solution: Refer to the problem in Question 4.2, where it is shown that in going from f_1 to f_2, the new frequency, the new capacitive reactance X_2 is given by

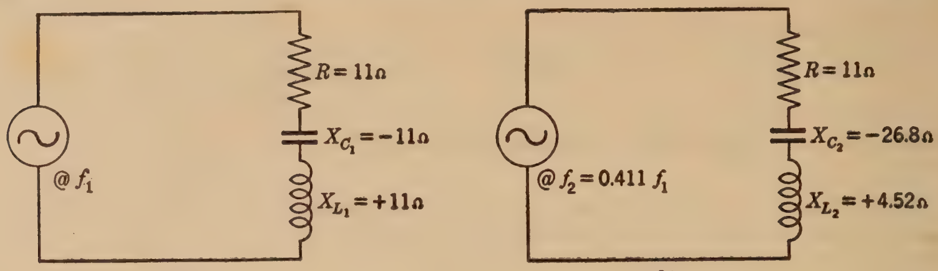
$$X_2 = \frac{f_1}{f_2} X_1$$

while the new inductive reactance X_2 is given by

$$X_2 = \frac{f_2}{f_1} X_1 \qquad \text{(See Figure 65.)}$$

The impedance of the series circuit composed of resistance and reactance is expressed thus:

$Z = \sqrt{R^2 + (X_{\text{total}})^2}$, where R = circuit resistance,
X_{total} = circuit reactance.



(a) (b)

FIG. 65. Problem in a-c circuit theory.

Now apply the above relations and solve for the given problem. In the problem as stated:

(1) Original circuit with f_1, the given values are:

$$R = 11 \text{ ohms},$$

$$X_{c_1} = -11 \text{ ohms},$$

$$X_{L_1} = +11 \text{ ohms}.$$

(2) Circuit when f_2 equals 0.411 times f_1; the values needed to insert in the impedance formula are:

$$R = 11 \text{ ohms (resistance remains the same)},$$

$$X_{c_2} = \frac{f_1}{f_2} X_{c_1} = \frac{f_1}{0.411 f_1} (-11) = -26.8 \text{ ohms},$$

$$X_{L_2} = \frac{f_2}{f_1} X_{L_1} = \frac{0.411 f_1}{f_1} (+11) = 4.52 \text{ ohms}.$$

Therefore, $X_{\text{total}} = X_{c_2} + X_{L_2} = -22.28$ ohms. Now insert the new total reactance value, -22.28 ohms, to find Z, thus:

$$Z = \sqrt{R^2 + (X_{\text{total}})^2} = \sqrt{11^2 + (-22.28)^2} = 24.8 \text{ ohms}$$

4.5. *Question.* **How many single-phase wattmeters are required to measure the power in a three-phase a-c circuit? Describe how this is done.**

Answer. The following describes the use of two wattmeters to measure power in a three-phase three-wire system: Connect the two current coils in any two lines. To the remaining line connect one terminal of each voltage coil. Each of the other terminals of the voltage coils should then be connected to the lines containing the corresponding current coils. The power taken by the load is the algebraic sum of the two readings. (See Figure 66.)

Note. It would be possible to use a single wattmeter in a balanced three-phase wye or delta connected system.

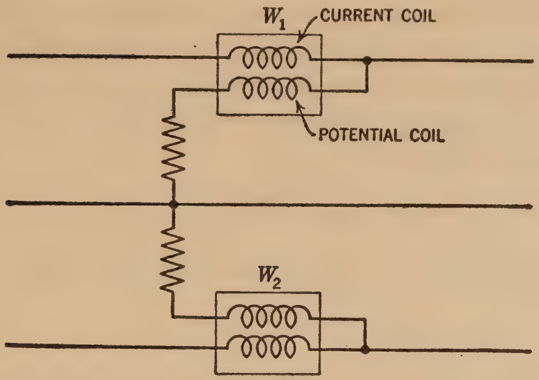


FIG. 66. Wattmeters connected in a three-phase circuit.

4.6. ***Question.*** **If an alternating current of 5 amperes flows in a series circuit composed of 12 ohms resistance, 15 ohms inductive reactance, and 40 ohms capacitive reactance, what is the voltage across the circuit?**

Answer. 138.5 volts.

Solution: The voltage across a circuit is equal to the current times the magnitude of the impedance, that is, $E = IZ$. To apply this formula we must find the value of the impedance, Z, since the current, I, is a given value. The impedance, Z, is determined as follows:

$$Z = \sqrt{R^2 + (X_{\text{total}})^2}$$

Given values to be inserted in above formula,

$$\text{where } I = 5 \text{ amperes,}$$
$$R = 12 \text{ ohms,}$$
$$X_{\text{total}} = X_L + X_c = 15 - 40 = -25 \text{ ohms.}$$

Then $Z = \sqrt{12^2 + (-25)^2} = \sqrt{144 + 625} = 27.7$ ohms.

Therefore $E = IZ = 5 \times 27.7 = 138.5$ volts.

4.7. ***Question.*** **A series circuit contains resistance, inductive reactance, and capacitive reactance. The resistance is 7 ohms, the inductive reactance is 8 ohms, and the capacitive reactance is unknown. What value must this condenser have in order that the total circuit impedance be 13 ohms?**

Answer. The reactance of the condenser is 18.95 ohms.

Solution: The impedance formula is used in the solution of this problem.

$$Z = \sqrt{R^2 + (X_{\text{total}})^2}$$

$$13 = \sqrt{7^2 + (X_{\text{total}})^2}$$

Squaring both sides

$$169 = 49 + (X_{\text{total}})^2$$

$$(X_{\text{total}})^2 = 120, \text{ whence } X_{\text{total}} = \pm 10.95$$

Now $X_{\text{total}} = X_L + X_c = 8 + X_c = \pm 10.95$ ohms.

The next step is to determine that reactance value for the condenser which will give a *negative* value, since X_{total} is either *plus* or *minus* 10.95 ohms, as worked out above. This result provides two possibilities, or cases, but only the case giving a *negative* value for capacitive reactance will be the correct one. This part of the problem is worked out as follows:

Case 1. $X_L + X_c = \pm 10.95$ ohms.

If $8 + X_c = +10.95$, then $X_c = +2.95$, which is obviously impossible.

Case 2. $X_L + X_c = \pm 10.95$ ohms.

If $8 + X_c = -10.95$, then $X_c = -18.95$, which is correct because this value can be obtained by the use of a condenser. Therefore

$$X_c = -18.95 \text{ ohms,}$$
$$\text{or } 18.95 \text{ capacitive ohms.}$$

Note. A problem similar to the one just worked out might be encountered sometime which asks for the **capacity** of the condenser. In this case the **frequency** should be stated in the question. Therefore, if the frequency were given and the capacitive reactance were determined as in this example the capacitance value of the condenser could be readily found from

$$X_c = \frac{1}{2\pi fC}, \quad \text{or} \quad C = \frac{1}{2\pi fX_c}$$

4.8. *Question.* What is the total reactance of two inductances connected in series with zero mutual inductance?

Answer. The total reactance is the sum of the two individual reactances, $X_1 + X_2$, when the mutual inductance is zero.

Proof: The formula for total inductance is

$$L_{\text{total}} = L_1 + L_2 \pm 2M$$

In the given problem where mutual inductance, M, is equal to zero, 0, then

$$L_{\text{total}} = L_1 + L_2$$

whence

$X_{\text{total}} = X_1 + X_2$, where X_1 and X_2 are the individual reactances of the coils.

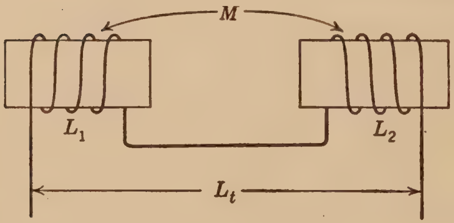


FIG. 67. Mutual inductance.

Note. Since M is equal to zero, it is immaterial whether the coils are aiding or opposing, as shown in Figure 67.

4.9. *Question.* If an alternating voltage of 115 volts is connected across a parallel circuit made up of a resistance of 30 ohms, an inductive reactance of 17 ohms, and a capacitive reactance of 19 ohms, what is the total circuit current drain from the source?

Answer. 3.91 amperes.

Solution: The first step is to find the current in each branch by applying Ohm's law, thus

$$I_R = \frac{E}{R} = \frac{115}{30} = 3.84 \text{ amperes}$$

$$I_L = \frac{E}{X_L} = \frac{115}{17} = 6.77 \text{ amperes (lag)}$$

$$I_c = \frac{E}{X_c} = \frac{115}{19} = 6.05 \text{ amperes (lead)}$$

Refer to Figure 68, where the relation between the reactances and the resistance is shown vectorially. Therefore, the total current, I_o, is given by

$$\begin{aligned} I_0 &= \sqrt{I_R{}^2 + (I_c - I_L)^2} \\ &= \sqrt{(3.84)^2 + (-0.72)^2} \\ &= \sqrt{15.27} = 3.91 \text{ amperes} \end{aligned}$$

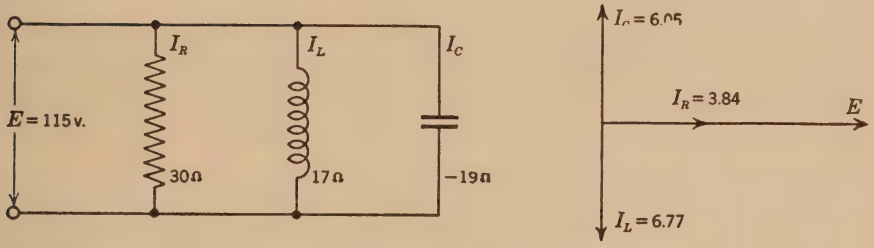


FIG. 68. Problem in a-c circuit theory.

4.10. *Question.* When two coils of equal inductance are connected in series, with unity coefficient of coupling and their fields in phase, what is the total inductance of the two coils?

Answer. The total inductance is four times the inductance of either coil since they are alike. That is, where L is the inductance of each coil the total inductance in this problem is $4L$.

Solution: See Figure 67. The formula for total inductance is

$$L_{\text{total}} = L_1 + L_2 \pm 2M, \quad \text{where } M = k\sqrt{L_1L_2}.$$

The conditions in this case are as follows:

(1) $L_1 = L_2 = L$, where L is the inductance of each coil.
(2) $k = 1$, coefficient of coupling.
(3) Coils are in series aiding.

$$\text{Therefore, } L_{\text{total}} = L_1 + L_2 + 2M$$
$$= L + L + 2L = 4L$$

Note that since k is equal to one, 1, and L_1 and L_2 are equal, then M is equal to L, which is proved as follows:

$$M = k\sqrt{L_1L_2} = 1\sqrt{L^2} = L$$

4.11. *Question.* If a power transformer has a primary voltage of 4,400 volts and a secondary voltage of 220 volts, and the transformer has an

efficiency of 98 per cent, when delivering 23 amperes of secondary current, what is the value of the primary current?

Answer. 1.173 amperes.

Solution: The secondary power is

$$P_{\text{sec.}} = E_{\text{sec.}} I_{\text{sec.}} = 220 \times 23 = 5{,}060 \text{ watts.}$$

The primary power taking into account an efficiency, *Effic.*, of 98 per cent is

$$P_{\text{pri.}} = \frac{P_{\text{sec.}}}{\mathit{Effic.}} = \frac{5{,}060}{0.98} = 5{,}160 \text{ watts}$$

Therefore the primary current is

$$I_{\text{pri.}} = \frac{P_{\text{pri.}}}{E_{\text{pri.}}} = \frac{5{,}160}{4{,}400} = 1.173 \text{ amperes}$$

4.12. ***Question.*** **Why is it impossible to obtain unity coupling in radio-frequency transformers?**

Answer. In radio-frequency transformers it is impossible to obtain unity coupling because not all of the flux produced by the primary links with the secondary winding. Unity coupling would be possible only if every line of force produced by a primary winding linked with the secondary winding; in a radio-frequency transformer there are leakage lines in the space or air.

4.13. ***Question.*** **Three single-phase transformers, each with a ratio of 220 to 2,200 volts, are connected across a 220-volt three-phase line, primaries in delta. If the secondaries are Y-connected, what is the secondary line voltage?**

Answer. Secondary line voltage is 3,810 volts.

Solution: In the working out of this problem we need to know that the voltage
7 across any pair of secondary lines is equal to the voltage of a single winding multiplied by 1.73; note that $\sqrt{3} = 1.73$.

Pri. Phase Voltage = Pri. Line Voltage = 220 volts

and

Sec. Phase Voltage = 2,200 volts

Therefore Sec. Line Voltage = $\sqrt{3}$ (2,200) = 3,810 volts.

4.14. ***Question.*** **What factors determine the core losses in a transformer?**

Answer. The core losses are due to the following:

(*a*) Eddy current losses varying as the square of the frequency.

(*b*) Hysteresis losses varying as the 1.6 power of the frequency.

4.15. ***Question.*** **What circuit constants determine the "copper" losses of a transformer?**

Answer. The "copper" losses are determined by the "hot" resistances of the primary and secondary winding or windings.

Note. For any one winding the "copper" loss is given by

$P = I^2R_e$, where I = current,
R_e = "hot" resistance of winding,
P = copper loss of winding.

4.16. *Question.* Draw a schematic wiring diagram of a three-phase transformer with delta-connected primary and Y-connected secondary.

Answer. See Figure 69.

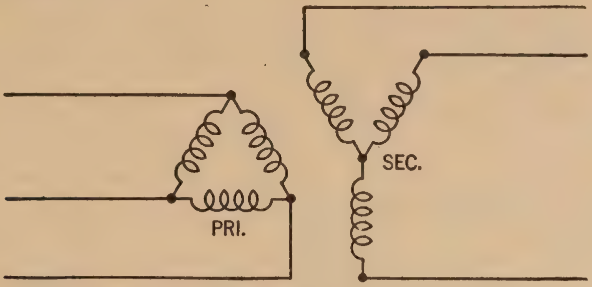


FIG. 69. Three-phase transformer.

4.17. *Question.* In a class A amplifier, what ratio of load impedance to dynamic plate impedance will give the greatest plate efficiency?

Answer. For a linear tube, of amplification factor μ, plate resistance R_p, voltage E_{bb}, and a bias voltage $E_c = 3E_{bb}/4\mu$, the maximum efficiency, as well as power output, is obtained when the ratio is 2:1. This represents the conditions for a practical case.

Note. The greatest plate-circuit efficiency, however, can be obtained if the ratio is made infinite since efficiency increases with the load resistance. Unfortunately, under those conditions, the power output would be negligible.

4.18. *Question.* What factor(s) determine the ratio of impedances which a given transformer can match?

Answer. The *turns ratio* determines the impedance match. Assuming a transformer with good coupling, that is, close to unity, then

$$\text{(Turns ratio)}\ \frac{N_2}{N_1} = \sqrt{\frac{Z_s}{Z_p}},$$

where N_1 = number of primary turns,
N_2 = number of secondary turns,
Z_p = primary Z to be matched,
Z_s = secondary Z to be matched.

Three other forms of the above turns ratio formula are

$$Z_p = \left(\frac{N_1}{N_2}\right)^2 Z_s, \quad \text{or} \quad \frac{Z_p}{Z_s} = \left(\frac{N_1}{N_2}\right)^2, \quad \text{or} \quad \frac{Z_s}{Z_p} = \left(\frac{N_2}{N_1}\right)^2$$

4.19. *Question.* If a transformer having a turns ratio of 10 to 1 works into a load impedance of 2,000 ohms and out of a circuit having an impedance of 15 ohms, what value of resistance may be connected across the load to effect an impedance match?

Answer. The resistance must be 6,000 ohms.

Solution: See Figure 70. In order to effect an impedance match, the impedance to the right of terminals 3–4 must equal 1,500 ohms, that is,

$$R_{3\text{-}4} = \left(\frac{N_2}{N_1}\right)^2 \times 15 = 1{,}500 \text{ ohms}$$

Hence, $\dfrac{1}{1{,}500} = \dfrac{1}{2{,}000} + \dfrac{1}{R}$, or $\dfrac{1}{R} = \dfrac{1}{1{,}500} - \dfrac{1}{2{,}000}$.

Then $\dfrac{1}{R} = \dfrac{1}{6{,}000}$, or $R = 6{,}000$ ohms.

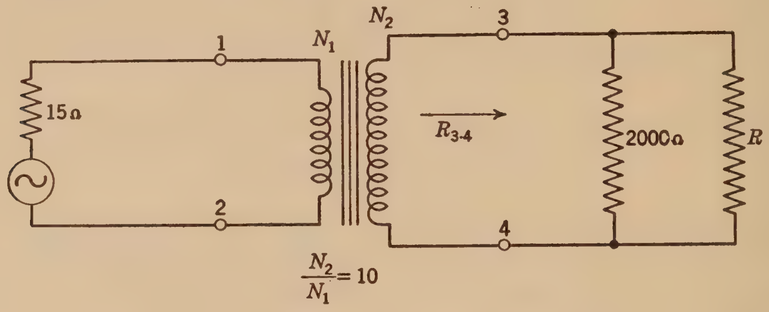


FIG. 70. Problem.

4.20. *Question.* **What is the purpose of effecting impedance matches in radio equipment?**

Answer. The purpose of effecting impedance matches in general is to provide the greatest transfer of power between pieces of equipment, or between source and load, and eliminate reflections at the point of transfer. Also, a proper impedance match is necessary to prevent standing waves in a transmission line.

4.21. *Question.* **In a class C radio-frequency amplifier, what ratio of load impedance to dynamic plate impedance will give the greatest plate efficiency?**

Answer. See Question 4.17.

4.22. *Question.* **If a lamp, rated at 100 watts and 115 volts, is connected in series with an inductive reactance of 355 ohms and a capacitive reactance of 130 ohms across a voltage of 220 volts, what is the current value through the lamp?**

Answer. The current in the lamp is 0.843 ampere.

Solution: First find the lamp resistance, using formula 1; next the circuit impedance, using formula 2; and last the lamp current, using formula 3, as follows:

(1) (Lamp resistance) $R = \dfrac{E_r^2}{P}$, where E_r = rated voltage,
P = rated power in watts.

(2) $Z = \sqrt{R^2 + (X_L + X_c)^2}$, where R = resistance (of lamp in this case),
$X_L = 2\pi fL$ = inductive reactance,
$X_c = 2\pi fC$ = capacitive reactance.

(3) $I = \dfrac{E}{Z}$, where E = impressed voltage,
Z = total impedance,
I = current.

The above formulas are now used to apply to the given problem: (See Figure 71.)

(1) $$R = \frac{E_r^2}{P} = \frac{115^2}{100} = \frac{13{,}230}{100} = 132.3 \text{ ohms}$$

(2) $$Z = \sqrt{(132.3)^2 + (355 - 130)^2} = \sqrt{17{,}500 + 50{,}600} = 261$$

(3) $$I = \frac{E}{Z} = \frac{220}{261} = 0.843 \text{ ampere}$$

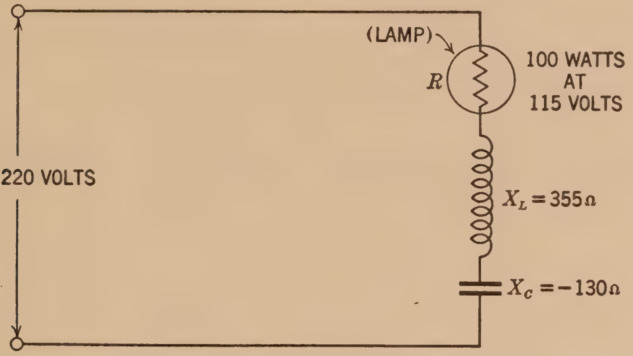


FIG. 71. Problem in a-c circuit theory.

4.23. *Question.* If an a-c series circuit has a resistance of 12 ohms, an inductive reactance of 7 ohms, and capacitive reactance of 7 ohms, at the resonant frequency, what will be the total impedance at twice the resonant frequency?

Answer. The total impedance is 15.96 ohms at the double frequency.

Solution: The new frequency being twice the original frequency will make the new inductive reactance twice the original inductive reactance, or $2X_L = 2 \times 7 = 14$ ohms.

Note that the inductive reactance varies **directly** as the multiplication factor by which the frequency is changed; in this case the frequency was increased twice; therefore 2 is the multiplication factor.

However, the new frequency, being twice the original frequency, will make the capacitive reactance one-half the original capacitive reactance, because capacitive reactance varies **indirectly** as the multiplication factor; in this case the new capacitive reactance is $X_c/2 = 7/2 = -3.5$ ohms.

Now apply the impedance formula in the usual way, inserting the new X_L and X_c values at the double frequency, and assuming that the resistance, 12 ohms, remains the same in each case

$$Z = \sqrt{R^2 + (X_L - X_c)^2}$$

$$Z = \sqrt{12^2 + (14 - 3.5)^2} = 15.96 \text{ ohms}$$

4.24. *Question.* In a parallel circuit composed of an inductance of 150 microhenrys and a capacitance of 160 micromicrofarads what is the resonant frequency?

Answer. 1,027 kilocycles, or 1.027 megacycles.

Solution: Since the resistance is assumed to be negligible, the frequency of parallel resonance is the same as that of series resonance, that is,

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{6.28\sqrt{LC}} = \frac{0.1592}{\sqrt{LC}}, \quad \text{where } L = \text{henrys}, \; C = \text{farads}.$$

Now convert the given values of L and C into henrys and farads, respectively,

$$\text{where } L \text{ (in henrys)} = 150\mu h \times 10^{-6}$$
$$\text{and } C \text{ (in farads)} = 160\mu\mu fd \times 10^{-12}$$

and insert these values in the frequency formula as follows:

$$f = \frac{0.1592}{\sqrt{150 \times 10^{-6} \times 160 \times 10^{-12}}} = \frac{0.1592}{10^{6}\sqrt{0.0240}} = \frac{0.1592 \times 10^{6}}{\sqrt{0.0240}}$$
$$= 1.027 \times 10^{6} \text{ cycles per second or } 1.027 \text{ megacycles}$$

Steps not shown in the operation above to simplify the denominator are: $\sqrt{150 \times 10^{-6} \times 160}$ equals $\sqrt{0.0240}$ and $\sqrt{10^{-12}}$ equals 10^{-6}.

Note. If the resistance of the coil is appreciable, then the frequency of parallel resonance is given by

$$f = \frac{1}{2\pi\sqrt{LC}}\sqrt{1 - \frac{CR_L^2}{L}}, \quad \text{where } L = \text{coil inductance}, \; R_L = \text{effective resistance of coil}, \; C = \text{condenser capacitance}.$$

also, $f = \dfrac{1}{2\pi\sqrt{LC}}\sqrt{1 - \dfrac{1}{Q_L^2}}$, where L and C are as above, and Q_L is the coil Q in the vicinity of resonance

4.25. *Question.* What value of capacitance must be shunted across a coil having an inductance of 56 microhenrys in order that the circuit resonate at 5,000 kilocycles?

Answer. 18.1 micromicrofarads.

Solution: The formulas needed for this solution are

$$f = \frac{1}{2\pi\sqrt{LC}} \quad \text{(assuming } R \text{ negligible)}$$

$$C = \frac{1}{(2\pi)^2 f^2 L} \quad \text{(solving for } C\text{)}$$

In the given problem:

$$f = 5 \times 10^{6} \text{ cycles per second, or } f^2 = 25 \times 10^{12}$$

and

$$L = 56 \times 10^{-6} \text{ henrys.}$$

Therefore

$$C = \frac{1}{39.5(25 \times 10^{12})56 \times 10^{-6}} = 18.1 \text{ micromicrofarads}$$

4.26. ***Question.*** **Why may it be desirable to ground all components of a speech amplifier at a common point?**

Answer. A speech amplifier will operate with greater stability and troublesome coupling effects will be avoided when the circuit elements are balanced to ground. This includes grounding center-taps, cores, metal housings, and so on. The use of a common ground eliminates the effects of varying ground potentials between the components, or in other words, only low potential difference levels exist between the circuit elements when terminated at a common point. Usually the common point connects to the metal chassis on which the amplifier parts are mounted.

4.27. ***Question.*** **Why should impedances be matched in speech-input equipment?**

Answer. Impedances should be matched to effect maximum transfer of power; to prevent reflections and consequent deviations from flatness in frequency response; to prevent resultant echo effects in long lines.

4.28. ***Question.*** **What is the purpose(s) of H or T pad attenuators?**

Answer. The purpose of H or T pad attenuators is to produce a desired decrease or attenuation in power level, while keeping the impedances on either side of the pad matched. In this way the loss or attenuation is the same for all frequencies in the audio range. H-pad balanced to ground.

4.29. ***Question.*** **Why are grounded center-tap transformers frequently used to terminate program wire lines?**

Answer. A program wire line is balanced to ground so that unwanted voltages induced in the line by outside influences, or stray fields, are practically balanced out. Besides reducing noise picked up by the line, the ground provides a drain for any static charges that might also cause noise. A better frequency response results with the line balanced to ground.

4.30. ***Question.*** **What is the purpose of a "line pad"?**

Answer. The purpose of a "line pad" is to isolate the line amplifier from the varying impedance of the telephone line. A pad having an attenuation of 10 decibels or more has the property of presenting a practically pure resistive impedance at one pair of terminals regardless of the value or kind of impedance connected to its other pair of terminals. Thus the "line pad" presents a practically pure resistance termination to the line amplifier regardless of how the impedance of the telephone line varies on the other end of the pad.

4.31. ***Question.*** **Why are electrostatic shields used between windings in coupling transformers?**

Answer. Electrostatic shields are used to prevent so far as possible the transfer of energy through the capacitive coupling between coils. With the capacitive coupling almost eliminated, the transfer of energy from primary to secondary is then effected principally by magnetic lines of force, or inductive coupling. When the coupling is practically entirely magnetic it minimizes the transfer of noises due to static and interference pick-up and acts to suppress harmonic transfer in r-f transformers.

4.32. ***Question.*** **Draw a simple diagram showing four mixers connected** in series parallel, using compensating resistors and feeding a balanced load with proper matching.

Answer. See Figure 72.

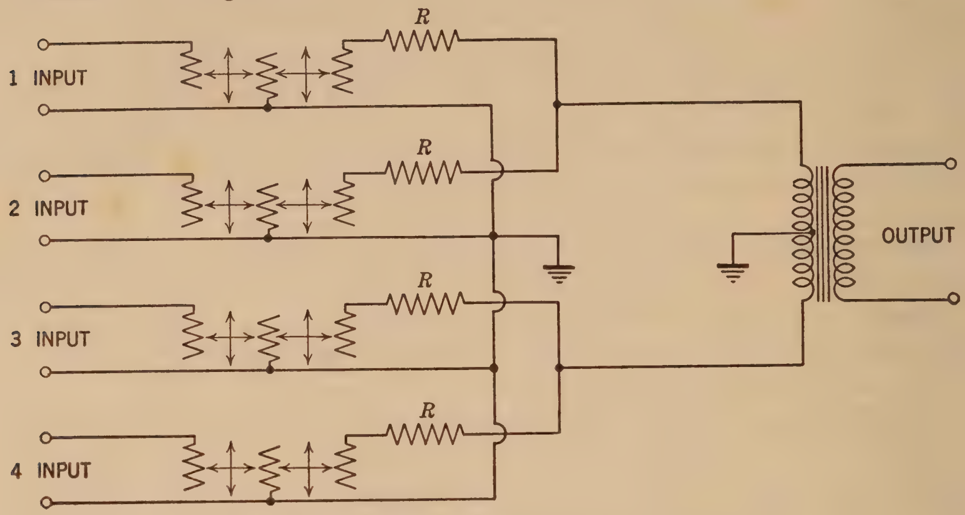


FIG. 72. Four mixers in series-parallel arrangement.

4.33. *Question.* Why is it preferable to isolate the direct current from the primary winding of an audio transformer working out of a single vacuum tube?

Answer. The direct current tends to saturate the core and reduce the inductance of the primary. This in turn tends to attenuate the low frequencies, as well as distort them.

4.34. *Question.* Draw a simple diagram of a single stage triode preamplifier employing direct current isolation of the output transformer primary.

Answer. See Figure 73.

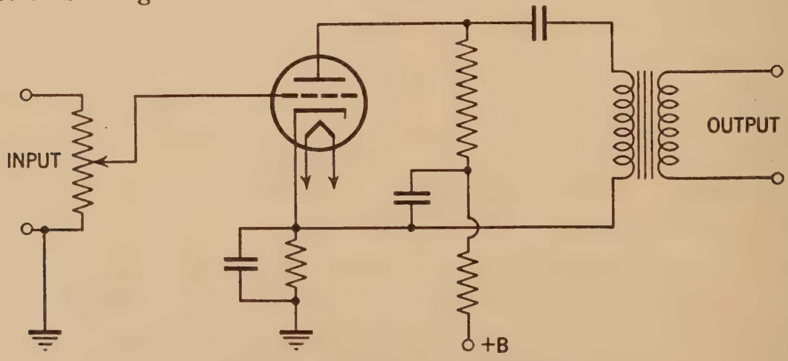


FIG. 73. Illustrating plate d-c isolation.

4.35. *Question.* Why are preamplifiers sometimes used ahead of mixing systems?

Answer. The preamplifier raises the level of the signal to a point where subsequent attenuation in a mixer will not reduce it below the minimum required for good signal-to-noise ratio. Also, if one signal source has inherently more output than another, it is advisable to bring the level of the latter up to that of the former before mixing by means of a preamplifier, so that the two "fader" settings on the mixer will be more nearly alike.

4.36. *Question.* **What is the purpose of a variable attenuator in a speech input system?**

Answer. The purpose of a variable attenuator is to enable the volume level to be adjusted (monitored) so that the system is not overloaded for loud sounds, nor the signal "swamped" out by noise when the sound is very weak.

4.37. *Question.* **In a low-level amplifier using degenerative feedback, at a nominal midfrequency, what is the phase relationship between the feedback voltage and the input voltage?**

Answer. The relationship is that of phase opposition, that is, the feedback voltage is 180° out of phase with the input voltage.

4.38. *Question.* **Under what circumstances will the gain-per-stage be equal to the voltage amplification factor of the vacuum tube employed?**

Answer. The gain-per-stage will be equal to the gain of the tube only when the load impedance is infinite; however, this is a theoretical condition. For a practical case, in a resistance-coupled amplifier the gain-per-stage is equal to the voltage amplification of the tube.

Note. The following formula gives the relation between the voltage across the load (gain-per-stage) and the voltage amplification factor of the tube:

$$\text{Voltage across load} = -\mu e_s \frac{Z_L}{R_p - Z_L},$$

where Z_L = load impedance,
R_p = plate impedance,
μe_s = voltage amplification factor.

Note that $E_{\text{load}} = -\mu e_s$ when $R_p = 0$.

4.39. *Question.* **Why is a high-level amplifier feeding a program transmission line generally isolated from the line by means of a pad?**

Answer. The use of a pad allows the level of the input to a program line to be kept within the required limits, thus preventing overloading the line, which might occur if a high-level amplifier were connected directly to the line.

Further benefits of a pad in this connection are that a more perfect impedance match is maintained and the pad, acting as a pure resistance, readily dissipates any energy in line reflections so that the reflections do not get back to the amplifier. Also, because the pad isolates the line from the amplifier, improved frequency characteristics are noticeable, the reason being that the capacitance of the line is removed from the plate circuit of the final amplifier stage; if this capacitance were left across the line it would act to bypass high frequencies and thus reduce the high-frequency response.

4.40. *Question.* **What is the result of deliberately introduced degenerative feedback in audio amplifiers?**

Answer. The results of deliberately introduced degenerative feedback in an audio amplifier are:

(*a*) Frequency response is flattened.

(*b*) Distortion is reduced.

(*c*) Signal-to-noise (developed in the amplifier) ratio is improved.

(*d*) Gain is stabilized, that is, rendered more independent of line voltage and tube variations.

4.41. *Question.* What unit has been adopted by leading program transmission organizations as a volume unit and to what power is this unit equivalent?

Answer. The unit recently adopted is the *volume unit,* or *vu.* This new standard reference level is equivalent to 1 milliwatt in 600 ohms.

Discussion. The volume unit is the same as the decibel, *db,* except that it is based on a zero reference level of 1 milliwatt (0.001 watt). The adoption by the industry of 1 milliwatt for 0 db as the calibration of the new reference volume unit removes the confusion which has existed for many years when different reference levels were used for calibration. For example, one organization used 6 milliwatts and another 12.5 milliwatts as the power level for 0 db. The circuit across which the new volume indicator instrument is calibrated has an impedance of 600 ohms; thus the power level and the impedance adopted standardizes the volume unit, *vu.*

4.42. *Question.* What is meant by "stabilized feedback"?

Answer. By "stabilized feedback" is meant inverse or degenerative feedback.

Note. See answers to Questions 4.37 and 4.40.

4.43. *Question.* Why are program circuits, using telephone lines, usually fed in at a level of about 12 milliwatts?

Answer. When the input level to a program line conforms to the telephone company requirements it ensures keeping cross talk interference, line noises, and distortion at a minimum. For example, if the proper level were exceeded, a repeating amplifier would overload and cause distortion, or in a cable carrying other lines there would be some interference set up. A level adjusted too low might allow the line noises and hum to override the signal and become objectionable.

4.44. *Question.* What is the purpose of a line equalizer?

Answer. A line equalizer is used to introduce a *loss* at lower frequencies to compensate for the loss at higher frequencies which a line causes owing to the bypassing effect of its distributed capacity. When properly adjusted, an equalizer corrects the high-frequency loss characteristic of a line, which then gives the line a flat-frequency characteristic. This means that all frequencies coming out at the end of a line are relatively more nearly the same in level as when they entered the line. In other words, the "lows" are reduced by the equalizer approximately to the same extent that the "highs" are naturally attenuated by the capacitance in a line. There would be marked discrimination in the "highs" if the ordinary line were used without an equalizer.

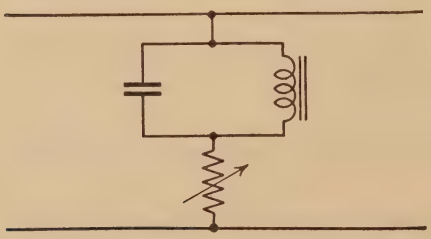


FIG. 74. Equalizer connected in a program line.

4.45. *Question.* Draw a diagram of an equalizer circuit most commonly used for equalizing wire-line circuits.

Answer. See Figure 74, showing the parallel type equalizer.

4.46. ***Question.*** **What methods are employed to avoid switching "clicks" in switching operations of mixing circuits?**

Answer. Switching clicks are avoided by using fade-out methods, by arranging the switching mechanism so that when interrupting a circuit an equivalent impedance is at the same time cut in, so there is no actual open position at switch contacts, and by the use of preamplifiers ahead of the mixing system.

4.47. ***Question.*** **Why is it generally unnecessary to equalize a short wire line program circuit?**

Answer. Advantage is taken of the fact that there is reflection in a short wire line due to mismatching. A short wire line naturally has a low impedance but the source which energizes the line has a relatively higher impedance. The reflections in the line hold up the level of the higher frequencies so that correction is not needed as in a long line, which attenuates these frequencies. However, to take practical advantage of the reflections in a short line and to avoid the use of an equalizer, a short line would be terminated in a transformer having a low primary inductance or low input impedance compared with the impedance of the line. The low impedance primary, comparing its effect relatively on the high frequencies and the low frequencies, will offer greater opposition to the "highs" and less to the "lows"; hence, this will favor the high-frequency response and compensate for high-frequency loss by the line.

4.48. ***Question.*** **What will be the probable result if one side of a properly terminated telephone line becomes grounded?**

Answer. The impedance relations between the line and the termination of the line would be upset. Several probable results of improper termination are:

(*a*) Loss of power (decreased energy transfer).
(*b*) Reflections.
(*c*) Incorrect equalization of line.
(*d*) Interference increased owing to line noises, cross-talk, and so on.

4.49. ***Question.*** **Describe the "vertical" system of transcription recording. Discuss its advantages and disadvantages.**

Answer. In this system the needle moves up and down in a vertical plane so that the *depth* of the groove varies according to the sound waves. This system is also called "hill and dale" recording.

Advantages: (*a*) Since a comparatively narrow groove is cut into the record in the vertical system it is possible to vary the depth greatly for wide ranges of sound power level and still permit a large number of grooves to be cut on the record to increase the playing time.

(*b*) The frequency response range of the vertical cutting over the life of the record runs much higher than for lateral cutting; this is true because the point of a hard needle, such as a diamond, shows practically no wear and continues to fit the groove and follow its wave form through many replayings, although the groove itself may show considerable wear in time.

(*c*) The fact that the point of the needle always fits the groove, which is triangular in shape at the bottom, is a special advantage.

Disadvantages: (*a*) A disadvantage in this system is that the weight of the point in cutting the impressions in the groove causes friction and this effect being in the same plane, *vertical plane*, as the recording itself results in a greater background of noise. Thus, in the vertical system the noise level is comparatively high.

(*b*) The grooves wear at a relatively faster rate than in the lateral system.

4.50. *Question.* **What type of microphone employs a coil of wire, attached to a diaphragm, which moves in a magnetic field as the result of the impinging of sound waves?**

Answer. The "dynamic" type of microphone. (See Question 3.44.)

4.51. *Question.* **What is the most serious disadvantage of using carbon microphones with high fidelity amplifiers?**

Answer. The "hissing" sound due to the carbon granules is emphasized and becomes objectionable.

4.52. *Question.* **Why are the diaphragms of certain types of microphones stretched?**

Answer. The purpose is to raise the first (lowest) resonant frequency, or natural period of the diaphragm, above the audio range, so that within the audio range the response is substantially flat. The higher frequencies, being closer to the diaphragm resonant frequency, would tend to be emphasized. This condition, however, can be obviated by sufficient damping out of this resonance.

4.53. *Question.* **Describe the "lateral" system of transcription recording. Discuss the advantages and disadvantages.**

Answer. In the "lateral" method the needle is supported in a manner that allows movement from *side to side* as it cuts the impressions in the groove, the groove being of constant depth.

Advantages: (*a*) The low noise level in this system is a distinct advantage. This low noise level is due to the free movement of the needle laterally but not vertically; therefore, as the needle rides through a groove its weight causes only a very slight friction on the bottom of the groove. That is to say, the vertical movement that would cause noise is very limited as compared with the lateral movement that produces the sound wave.

(*b*) The comparatively small wear laterally in the grooves with many replayings gives this type of recording better high-frequency response over a long period of use of the record and high quality reproduction for the first series of playings of the record.

Disadvantages: (*a*) A disadvantage lies in the comparatively wide groove which is necessary to record the varying sound intensity levels and to prevent overlapping or cutting into adjacent grooves laterally.

(*b*) The wider groove necessarily takes up a greater area on the record and, therefore, cuts down the playing time of the record.

(*c*) After many replayings the grooves will wear and cause lost motion in the travel of the needle back and forth so that the needle will not then follow as accurately the wave form of the sound impressions as would the needle in a vertically cut groove under similar conditions of wear.

4.54. *Question.* **Draw a simple schematic diagram of a grid bias modulation system, including the modulated radio-frequency stage.**

Answer. See Figure 75.

4.55. *Question.* **Draw a simple schematic diagram of a class B audio high-level system, including the modulated radio-frequency stage.**

Answer. See Figure 76.

4.56. *Question.* **Draw a simple sketch of the trapezoidal pattern on a cathode-ray oscilloscope screen indicating low percentage modulation without distortion.**

Answer. See Figure 77.

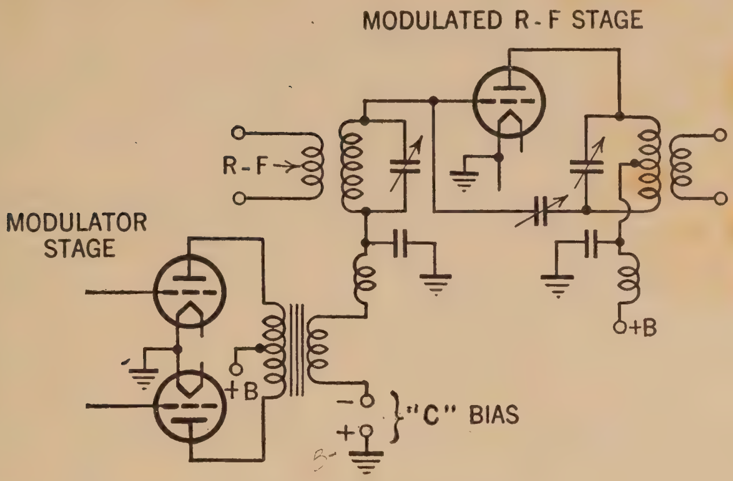


FIG. 75. Grid bias modulation.

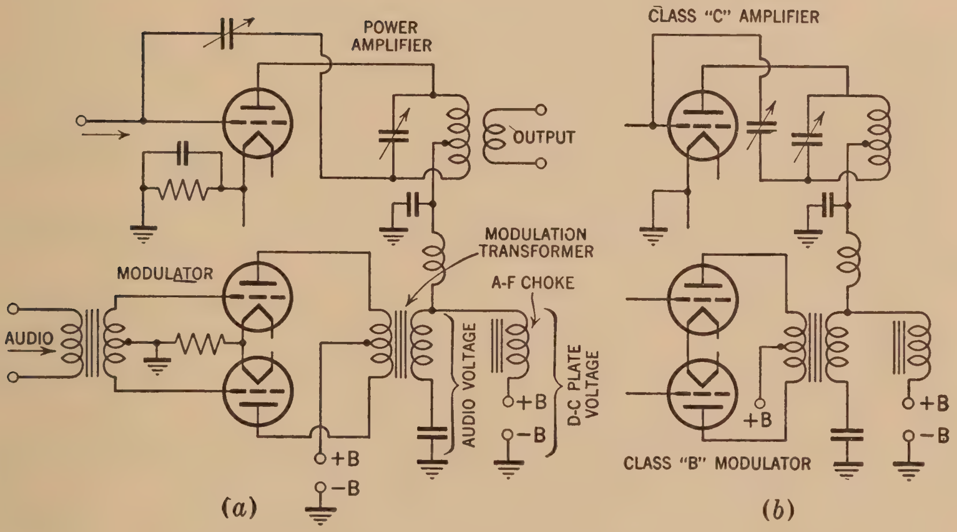
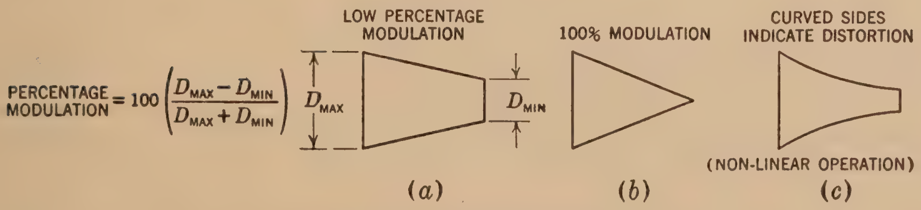


FIG. 76. Plate modulation; either circuit will answer the question.



$$\text{PERCENTAGE MODULATION} = 100\left(\frac{D_{MAX}-D_{MIN}}{D_{MAX}+D_{MIN}}\right)$$

FIG. 77. Trapezoidal patterns.

4.57. ***Question.*** **During 100 per cent modulation, what percentage of the average output power is in the side-bands?**

Answer. The side-bands represent 33⅓ per cent of the average output power.

Note. Under conditions of 100 per cent modulation the carrier power represents 66⅔ per cent of the total power, since the total power equals the sum of the side-band power and the carrier power.

4.58. ***Question.*** **Draw a schematic diagram of test equipment which may be used to detect carrier shift of a radiotelephone transmitter output.**

Answer. See Figure 78.

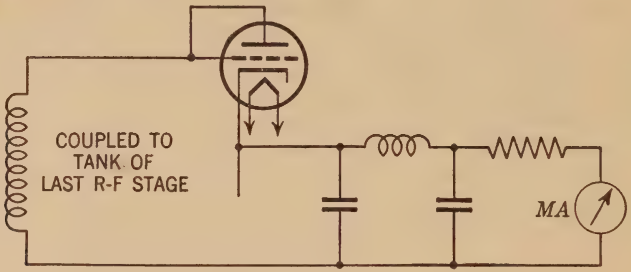


FIG. 78. Circuit for detection of carrier shift.

4.59. ***Question.*** **To what value is the d-c grid bias of a "grid bias modulated amplifier" normally adjusted?**

Answer. It is generally stated that for a grid bias modulated amplifier the bias is normally adjusted to 1½ to 2 times plate current cutoff value. For certain applications the bias adjustment may be 3 times cutoff value.

4.60. ***Question.*** **In radio equipment, what use is made of a fluorescent screen?**

Answer. The cathode-ray oscilloscope is an instrument which makes use of a fluorescent screen. The screen becomes luminous when struck by an electron beam, which permits the viewing of wave forms of voltages and currents in circuits under investigation. The rapidly moving light beam traces out patterns which show visually the characteristics of the energy applied to the plates of the cathode-ray tube. These patterns are useful in identifying frequency ratios and the effect of phase shift. Other applications are in television equipment.

4.61. ***Question.*** **What are the advantages and disadvantages of class B modulators?**

Answer. The advantages and disadvantages given below for class B modulators are based on a comparison with class A operation of modulators.

Advantages: (*a*) Higher plate efficiency. (*b*) Greater power output. (*c*) Lower power consumption. (*d*) Smaller tubes (less expensive).

Disadvantages: (*a*) Greater distortion, particularly for low-level signals. (*b*) Stage must be double-ended, employing two tubes. (*c*) Large signal driving power to grid is required. (*d*) Power supply for class B must have better regulation because of the steep plate current amplitude.

4.62. ***Question.*** **Why is frequency modulation undesirable in the standard broadcast band?**

Answer. A wider frequency band is required for a frequency modulated, FM, signal compared with amplitude modulation, AM, and for this reason only a very small number of FM broadcast stations could be accommodated in the present standard broadcast frequency band.

4.63. *Question.* **Describe what is meant by "series modulation."**

Answer. "Series modulation" is a system in which the d-c plate circuits of the modulator and the modulated r-f amplifier are connected in series. In this arrangement the modulator's plate connects to the cathode of the r-f amplifier with the positive high-voltage supply going to the plate of the latter tube and the negative to cathode of the modulator tube. This type of modulation finds application in European broadcast transmitters.

4.64. *Question.* **What is meant by "low-level" modulation?**

Answer. The term "low-level" indicates that modulation is produced at a point in a system where the power level is low compared with the power level at the output of the system.

4.65. *Question.* **If a preamplifier, having a 600-ohm output, is connected to a microphone so that the power output is minus 40 db, and assuming the mixer system to have a loss of 10 db, what must be the voltage amplification necessary in the line amplifier in order to feed plus 10 db into the transmitter line?**

Answer. The voltage amplification is 1,000 for this problem.

Solution: See Figure 79, which shows that the line amplifier must provide a gain of 60 db to give +10 db power output with a power input of −50 db.

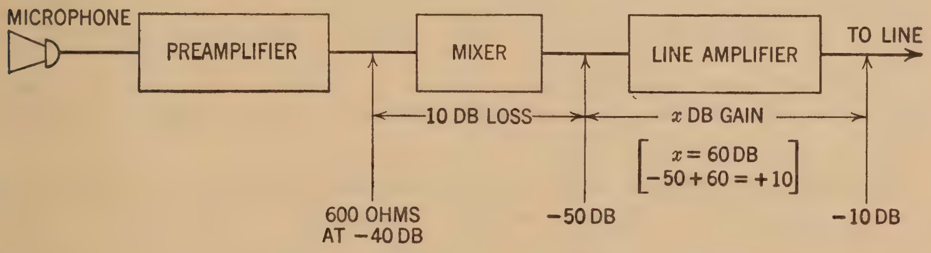


FIG. 79. Problem in voltage amplification.

Knowing the gain of the line amplifier to be 60 db, we insert this value for number of decibels, N_{db}, in the formula and then find the voltage ratio of the voltage out, E_{out}, and the voltage in, E_{in}, as follows:

$$N_{db} = 20 \log \frac{E_{out}}{E_{in}}$$

$$60 = 20 \log \frac{E_{out}}{E_{in}}$$

$$3 = \log \frac{E_{out}}{E_{in}}$$

$$\frac{E_{out}}{E_{in}} = \log^{-1} 3 = 1{,}000$$

Therefore $E_{out} = 1{,}000\, E_{in}$.

Alternative method to avoid use of a negative exponent.

$$\frac{E_{in}}{E_{out}} = \frac{1}{\log 3} = \frac{1}{1{,}000}$$

$$\frac{E_{out}}{E_{in}} = 1{,}000$$

Therefore $E_{out} = 1{,}000\, E_{in}$.

4.66. ***Question.*** **If the power output of a modulator is decreased from 1,000 watts to 10 watts, how is the power loss expressed in db?**

Answer. The power loss is 20 db, or it may be written −20 db to indicate *loss.*

Solution: To find the number of decibels, N_{db}, with the power ratio a given value, apply the db formula for power ratio as follows:

$$N_{\text{db}} = 10 \log \frac{P_2}{P_1}$$

$$N_{\text{db}} = 10 \log \frac{1{,}000}{10} = 10 \times \frac{10^2}{10^1} = 10 \times \frac{2}{1} = 20 \text{ db}$$

The steps in the reasoning which apply to this problem are as follows: The power ratio is 1,000/10 = 100; the log of the number 100 is 2, that is $100 = 10^2$ (the power to which 10 must be raised to equal 100 is the log); from the formula the number of decibels, N_{db}, is equal to 10 times the log of the power ratio, or $10 \times 2 = 20$ db.

4.67. ***Question.*** **In a modulated amplifier, under what circumstances will the plate current vary as read on a d-c meter?**

Answer. Plate d-c variations would most likely be due to overmodulation or excessive r-f excitation if the modulated amplifier stage itself were in proper adjustment. A number of other possibilities are insufficient grid bias, improper neutralization, improper adjustment of load impedance, unbalanced modulator, a defective tube, or conditions causing either positive or negative carrier shift.

Note. A very slight fluctuation of the plate d.c. is permissible in a class B or class C modulated amplifier, depending upon the nature of the signal, but for class A operation the fluctuation of plate current indicates distortion.

4.68. ***Question.*** **What could cause downward deflection of the antenna current ammeter of a transmitter when modulation is applied?**

Answer. The following gives a number of possibilities which could cause downward deflection, or downward "kick," of the antenna ammeter:

(*a*) Insufficient r-f excitation of the amplifier.

(*b*) Poor regulation of plate power supply, or low plate voltage.

Poor regulation would make the plate current crests less than normal but the troughs would be just as low and therefore the average plate current would be less.

Poor regulation might also reduce plate voltage on the previous stages and therefore reduce excitation voltage. The cause of poor regulation of the plate d-c supply might be an open filter condenser in the power supply, or insufficient output capacity in the filter.

(*c*) Overloading or distortion in the audio system.

Unsymmetrical modulating voltage wave.

(*d*) Improper adjustment of load impedance.

The r-f amplifier plate d-c resistance acts as a load on the modulator, and this load impedance might be too high or too low.

(*e*) Low filament voltage, or a weak tube having low emission.

If, for one reason or another, the peak filament emission is low then large positive grid potentials cannot increase the space current enough to supply both the grid and plate.

(*f*) Insufficient grid bias voltage.

Insufficient bias would probably cause a condition similar to (*e*), and in addition the plate might overheat owing to approximation of class A operation, that is, because of low efficiency.

(*g*) Improperly tuned tank circuit, or tank circuit *C* may be too low.

Poor tuned tank circuit might cause downward deflection because the plate current amplitudes are large and, therefore, the *IR* drop in the plate voltage supply would be greater than normal; hence, conditions in (*b*) would result.

4.69. *Question.* Under what conditions of operation of a class B linear amplifier will the plate dissipation be a maximum?

Answer. In a *radio-frequency* class B linear amplifier the plate dissipation is maximum with no modulation, because the plate current, I_b, is constant. In terms of plate efficiency, the plate efficiency is lowest at zero modulation and will be highest at 100 per cent modulation.

Note. In an *audio-frequency* class B linear amplifier the plate dissipation varies directly with the signal level.

4.70. *Question.* If 100 per cent modulation is obtained with an input level of 60 db, what percentage of modulation will be obtained when the input level is 45 db?

Answer. Approximately 17.8 per cent modulation is obtained for an audio input level of 45 db.

Solution: In this problem the *difference* between the given input levels, or 60 − 45 = 15 db, can be used to find the *voltage ratio* of the two inputs as follows:

$$N_{\mathrm{db}} = 20 \log \frac{E_1}{E_2}$$

$$15 = 20 \log \frac{E_1}{E_2}$$

$$\text{or, } \log \frac{E_1}{E_2} = \frac{15}{20} = 0.75$$

Since the antilog of 0.75 is 5.63, then

$$\frac{E_1}{E_2} = 5.63, \text{ the audio input voltage ratio}$$

Since modulation percentage is in direct proportion to audio input voltage it follows that the two modulation percentages (one given at 100 per cent and the other to be found) are proportional to their voltage ratio, hence

$$\frac{100 \text{ per cent}}{5.63} = 17.8 \text{ per cent modulation}$$

4.71. *Question.* When the light flashes on the panel of the modulation monitor, what is indicated?

Answer. The indicator light flashes as a warning that the modulation percentage for which the indicator has been set has been exceeded. If the modulation monitor had been set for 100 per cent the light flashes would indicate excessive peaks or overmodulation on peaks.

4.72. *Question.* Why is it desirable to maintain a comparatively high percentage of modulation in a radiotelephone transmitter?

Answer. A comparatively high percentage of modulation increases the useful transmission range or service area of the signal. At higher modulation levels there is a greater amount of power represented in the side-bands, or audio component, which convey the intelligence. Other benefits are that when a carrier is modulated sufficiently the carrier frequency interference area is reduced, and, also, as a carrier is modulated more fully there is a corresponding increase in the over-all efficiency of the transmitter.

4.73. *Question.* If tests indicate that the positive modulation peaks are greater than the negative peaks in a transmitter employing a class B modulator, what steps should be taken to determine the cause?

Answer. A check-up should be made of the following:

(*a*) Check grid bias voltage.

(*b*) Audio drive to modulator grids may be too high; check for overmodulation.

(*c*) Check emission of each modulator tube; each half of a push-pull stage should be balanced and doing equal work.

(*d*) Recheck tuning of the modulated amplifier plate tank circuit; insufficient plate tank *C* might cause this trouble.

(*e*) Improper neutralization.

4.74. *Question.* In a properly adjusted grid bias modulated radio-frequency amplifier, under what circumstances will the plate current vary as read on a d-c meter?

Answer. Overmodulation, or excessive audio drive, will cause this condition.

4.75. *Question.* What percentage increase in average output power is obtained at 100 per cent sinusoidal modulation as compared with average unmodulated carrier power?

Answer. The increase in average output power is 50 per cent.

4.76. *Question.* In a class C radio-frequency amplifier stage feeding an antenna system, if there is a positive shift in carrier amplitude under modulation conditions, what may be the trouble?

Answer. Causes of positive carrier shift are included in the following:

(*a*) Overmodulation.

(*b*) Improper neutralization.

(*c*) Plate tank circuit *C* too low.

(*d*) Insufficient r-f grid drive.

(*e*) Parasitic oscillations.

(*f*) Improper resonant conditions between antenna and final plate tank circuit.

4.77. *Question.* Name four causes of distortion in a modulated amplifier stage output.

Answer. Four causes of distortion in a modulated amplifier output stage are as follows:

(*a*) Overmodulation.

(*b*) Excessive r-f excitation, or overdrive.

(*c*) Improper load impedance match between modulator and modulated amplifier stage.

(*d*) Incomplete neutralization, or the presence of parasitic oscillations.

4.78. *Question.* Under what operating conditions will the efficiency of a grid bias modulated radio-frequency amplifier be a maximum?

Answer. The efficiency for grid bias modulation depends upon the percentage of modulation, the efficiency being highest on peaks at 100 per cent modulation.

Note. During a small part of the excitation cycle the grid may be driven positive, causing it to draw current and at this peak the efficiency is a maximum.

4.79. *Question.* If the plates of a class B modulator suddenly showed color, without excitation, what could be the cause?

Answer. Overheating of the plates would indicate excessive plate current, which could be caused by loss of bias, or insufficient bias, or if this were not the reason the trouble most likely would be due to feedback causing oscillation in the stage.

4.80. *Question.* If you decrease the percentage of modulation from 100 to 50 per cent, by what percentage have you decreased the power in the side-bands?

Answer. The power in the side-bands is decreased 75 per cent.

Explanation. The power with modulation is equal to the power of the carrier *plus* the power in the side-bands. This statement for any percentage modulation is expressed as follows:

$$P \text{ (with modulation)} = \left(1 + \frac{m^2}{2}\right) \times P \text{ (carrier, or without modulation)}$$

From this relation we also get

$$\boxed{P_{\text{side-bands}} = \frac{m^2}{2} \times P_{\text{carrier}}}$$

Hence $\frac{m^2}{2}$ can be used in a problem of this kind to determine the relation between the difference in percentage modulation and the corresponding difference in side-band power. The letter m is the modulation factor, used as follows: for 100 per cent modulation $m = 1$, and for 50 per cent $m = 0.5$.

Solution: Apply $\frac{m^2}{2}$ for each case.

Case 1. For 100 per cent modulation the side-band power, P_{sb}, to be expressed in per cent is found as follows:

$$P_{\text{sb}} = \frac{m^2}{2} = \frac{1^2}{2} = \frac{1}{2} = 0.5$$

and to express the value 0.5 in per cent we multiply 0.5 by 100, which equals 50 per cent. Thus, 50 per cent is the percentage of power in the side-bands at 100 per cent modulation.

Case 2. For 50 per cent modulation the side-band power, P_{sb}, also to be expressed in per cent, is found in a similar manner; thus

$$P_{sb} = \frac{m^2}{2} = \frac{0.5^2}{2} = \frac{0.25}{2} = 0.125$$

and this value given in per cent is $0.125 \times 100 = 12.5$ per cent. Hence, 12.5 per cent is the percentage of power in the side-bands at 50 per cent modulation.

The last step in working out this problem is to determine that a change in the side-band power from 0.5 (50 per cent) to 0.125 (12.5 per cent) represents a 75 per cent reduction. Since $50 \div 12.5 = 4$, it is seen that the smaller value is one-fourth of the larger one, and therefore the latter must be three-fourths of the whole.

4.81. *Question.* If a certain audio-frequency amplifier has an over-all gain of 40 db and the output is 6 watts, what is the input?

Answer. The input is 0.6 milliwatt.

Solution: The number of decibels, 40 db, equals 10 times the log of the ratio of the two powers, where x is the *input power* in this problem.

$$N_{db} = 10 \log \frac{P_1}{P_2}$$

$$40 = 10 \log \frac{6}{x}, \quad \text{or} \quad \log \frac{6}{x} = \frac{40}{10}$$

Hence, the log of the power ratio is 4, or

$$\log \frac{6}{x} = 4$$

and the antilog of 4 is $10^4 = 10{,}000$, then

$$\frac{6}{x} = 10{,}000$$

therefore

$$x = \frac{6}{10{,}000} = 0.0006 \text{ watt, or } 0.6 \text{ milliwatt.}$$

Note. The question might be interpreted to require finding the input in terms of decibels, or *db input* level, and again the same formula would be applied; thus

$$N_{db} = 10 \log \frac{P_1}{P_2}$$

Substituting the two known power levels

$$N_{db} = 10 \log \frac{6}{0.006} = 10 \times \log 1{,}000 = 10 \times 3 = 30 \text{ db}$$

Since the over-all gain minus the output equals the input

$$40 - 30 = -10 \text{ db, the audio input level}$$

4.82. *Question.* What is the purpose of a Faraday or electrostatic shield between the final tank circuit and the antenna circuit of a transmitter?

Answer. A Faraday screen is used to suppress harmonic energy from reaching the antenna and being radiated. The screen effectively reduces the capacity coupling between the coils through which harmonic frequencies pass through from the final tank to the antenna. The normal coupling and normal signal transfer are by means of the magnetic lines. If the shield is made of conductors they should be run perpendicular to the plane of the coils to prevent eddy current losses.

4.83. *Question.* If the field intensity of 25 millivolts per meter develops 2.7 volts in a certain antenna, what is its effective height?

Answer. 108 meters.

Solution: The problem is one in proportion. If the total voltage is 2.7 volts and for each meter the intensity is 25 millivolts, or 0.025 volts, then if we divide 2.7 by 0.025 we get the number of meters across which the 2.7 volts is developed. Hence, $2.7 \div 0.025 = 108$ meters.

Note. The problem can be stated as a proportion, thus: The total voltage is to the voltage across a section as the total height is to the length of that section, or

$$2.7 : 0.025 :: x : 1 \text{ meter}$$

The product of the means equals the product of the extremes, or

$$2.7 \times 1 = 0.025 \times x$$

$$0.025x = 2.7$$

therefore,

$$x = \frac{2.7}{0.025} = 108 \text{ meters, or approximately 355 feet}$$

4.84. *Question.* Draw a schematic diagram of a final amplifier with capacity coupling to the antenna which will discriminate against the transfer of harmonics.

Answer. See Figure 80.

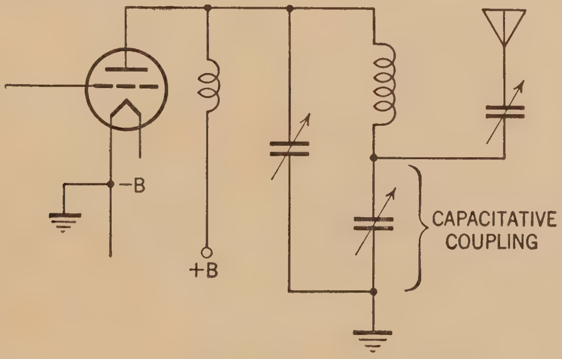


FIG. 80. Coupling condenser is common to both plate tank circuit and antenna.

4.85. *Question.* In what units is the field intensity of a broadcast station normally measured?

Answer. Radio field intensity is usually expressed in microvolts per meter or millivolts per meter.

4.86. *Question.* Draw a simple schematic diagram showing a method of coupling the radio-frequency output of the final power amplifier stage of a transmitter to a two-wire transmission line, with a method of suppression of second and third harmonic energy.

Answer. See Figure 81.

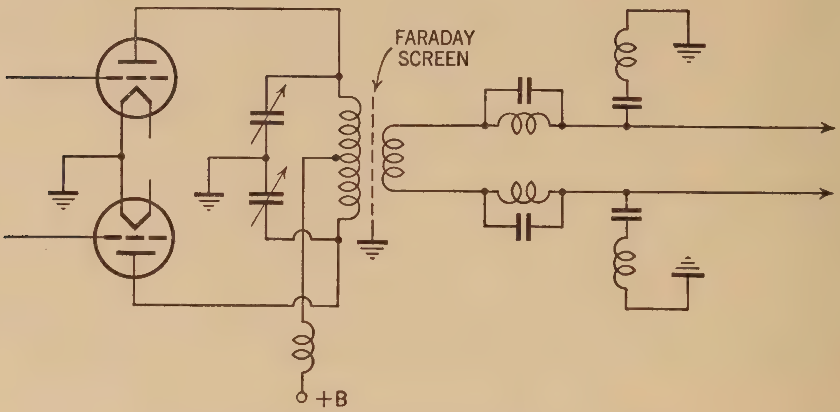


FIG. 81. Transmission line with harmonic suppression.

4.87. *Question.* Describe a method of determining "antenna resistance."

Answer. Two readings of the antenna current are taken, one with and one without a known resistance, R_k, in series with the antenna. The antenna resistance in ohms is obtained from the formula

$$R_a = \left(\frac{I_k}{I - I_k}\right) \times R_k,$$

where I = antenna current with R_k short-circuited,
I_k = antenna current with R_k in the circuit.

In making the measurement it is necessary to couple the oscillator loosely to the antenna and maintain the current in the oscillator constant.

Note. The method described above is from the *Institute of Radio Engineers Standards, Section 5, Antenna Resistance.* This section covers IRE standards on methods of measurement and tests.

4.88. *Question.* An antenna is being fed by a properly terminated two-wire transmission line. The current in the line at the input end is 3 amperes. The surge impedance of the line is 500 ohms. How much power is being supplied to the line?

Answer. 4,500 watts.

Solution: With proper termination the antenna resistance, R, equals the surge impedance, Z_0, of the line, or 500 ohms. Therefore, insert the given values in the power formula as follows:

$$\text{Power into line} = I^2R = 3^2 \times 500 = 4{,}500 \text{ watts, or } 4.5 \text{ kilowatts}$$

(plus line losses which are usually negligibly small)

4.89. *Question.* **If the daytime transmission line current of a 10-kilowatt transmitter is 12 amperes, and the transmitter is required to reduce to 5 kilowatts at sunset, what is the new value of the transmission line current?**

Answer. 8.47 amperes.

Solution: Apply the power formula, $P = I^2R$, but first applying it in the form to find the line impedance, R, and secondly, in the form to find current, I.
To find the resistance:

$$R = \frac{P}{I^2} = \frac{10{,}000}{12^2} = \frac{10{,}000}{144} = 69.5 \text{ ohms}$$

To find the new value of I at the new power, 5,000 watts

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{5{,}000}{69.5}} = \sqrt{72} = 8.47 \text{ amperes}$$

4.90. *Question.* **If the antenna current is 9.7 amperes for 5 kilowatts, what is the current necessary for a power of 1 kilowatt?**

Answer. 4.33 amperes.

Solution: (The preceding question is similar to this one.)
First, find the resistance of the antenna.

$$R = \frac{P}{I^2} = \frac{5{,}000}{(9.7)^2} = 53.2 \text{ ohms}$$

Second, find the current.

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{1{,}000}{53.2}} = 4.33 \text{ amperes}$$

4.91. *Question.* **What is the antenna current when a transmitter is delivering 900 watts into an antenna having a resistance of 16 ohms?**

Answer. 7.5 amperes.

Solution: Apply the power formula, $P = I^2R$, but in the following form,

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{900}{16}} = 7.5 \text{ amperes}$$

4.92. *Question.* **If the daytime input power to a certain broadcast station antenna having a resistance of 20 ohms is 2,000 watts, what would be the nighttime input power if the antenna current were cut in half?**

Answer. The nighttime input power would be 500 watts.

Solution: Apply the power formula first to find the current at the original power, 2,000 watts, so that this current value may be halved and applied again in the power formula to find the new power. To find the current, I, for 2,000 watts:

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{2{,}000}{20}} = \sqrt{100} = 10 \text{ amperes}$$

To find the new power at half the above current value, or 5 amperes

$$P = I^2R = 5^2 \times 20 = 25 \times 20 = 500 \text{ watts}$$

Note. An alternative method for solving this problem is to consider that the power varies as the square of the current; therefore, if the current is reduced one-half, the power is reduced one-fourth, that is, the original power of 2,000 watts is reduced one-fourth, which is 500 watts, the same answer. Here the value of the antenna resistance is not needed, although it is given in the statement of the question.

4.93. ***Question.*** **The d-c input power to the final stage is exactly 1,500 volts and 700 milliamperes. The antenna resistance is 8.2 ohms and the antenna current is 9 amperes. What is the plate efficiency of the final amplifier?**

Answer. The plate efficiency is 63.26 per cent.

Solution: The problem calls for finding the input power and the output power since plate efficiency equals **power out** divided by **power in.**

Input power: $P = IE = 0.7 \times 1{,}500 = 1{,}050$ watts

Output power: $P = I^2R = 9^2 \times 8.2 = 664.2$ watts

Plate efficiency: $\frac{P_{\text{out}}}{P_{\text{in}}} = \frac{664.2}{1{,}050} = 0.6326$, or 63.26 per cent

4.94. ***Question.*** **If the power output of a broadcast station is quadrupled, what effect will this have upon the field intensity at a given point?**

Answer. The field intensity would be *doubled.*

Solution: The point to note in this problem is that field intensity is measured in microvolts per meter or millivolts per meter, and therefore we are interested here in knowing how much the **voltage** changes for a given signal which is increased four times in **power.** According to $E = \sqrt{PR}$, the voltage varies as the square root of the power. Hence, 4 times the power means the voltage is increased 2 times. The resistance, R, remains unchanged.

4.95. ***Question.*** **The ammeter connected at the base of a Marconi antenna has a certain reading. If this reading is increased 2.77 times, what is the increase in output power?**

Answer. The power output is increased 7.67 times.

Solution: According to $P = I^2R$, the power varies as the square of the current; therefore, if the current is increased 2.77 times, the power is increased $(2.77)^2$ times, or 7.67 times.

4.96. ***Question.*** **If the power output of a broadcast station has been increased so that the field intensity at a given point is doubled, what increase has taken place in antenna current?**

Answer. The antenna current is increased two times.

Solution: If the signal is doubled in intensity at a given point the voltage which produces the signal is also doubled; field intensity is usually measured in *millivolts* per meter. Since the current is directly proportional to voltage the current is increased twice when the voltage is doubled and the resistance remains unchanged. This is a simple application of Ohm's law, where $I = E/R$.

4.97. ***Question.*** **If a transmitter is modulated 100 per cent by a sinusoidal tone, what percentage increase in antenna current will occur?**

Answer. The antenna current increases 22.5 per cent.

Solution: The effective current, or r.m.s. value, depends upon the percentage of modulation in accordance with

$$I = \sqrt{1 + \frac{m^2}{2}}$$

The amount of change of antenna current for different percentages of modulation can be found from the above relation. In this problem $m = 1$, since the modulation factor is 1 for 100 per cent. Solving for current, I, we get

$$I = \sqrt{1 + \frac{1^2}{2}} = \sqrt{1 + \frac{1}{2}} = \sqrt{1.5} = 1.225$$

and, therefore, the current at 100 per cent modulation is 1.225 times the current with no modulation. However, the question calls for *percentage* increase in current; or, in this case, 1.225 times a certain value of current is equivalent to a 22.5 per cent increase.

Alternative method. It is possible to reason this problem another way. Let a certain power, say 1, when unmodulated be increased 50 per cent, or 0.5; then at full modulation the total power will be 1.5, that is, the total power equals the sum of the carrier power and the side-band power. Since current varies as the square root of the power, the current in this problem will equal the square root of 1.5, or $I = \sqrt{1.5} = 1.225$ times increase. The *percentage* increase is 22.5 per cent.

4.98. *Question.* What is the ratio of the currents at the opposite ends of a transmission line, ¼ wavelength long, and terminated in an impedance equal to its surge impedance?

Answer. The ratio of the currents at opposite ends of the transmission line is 1 : 1, that is, the currents have the same value.

Discussion. The following conditions hold with regard to the transmission line involved in this problem:

(*a*) There are no reflections and no standing waves on the line.

(*b*) The signal power is merely attenuated owing to negligible losses of the line, the losses increase with increased length of line, and the current is the same all along the line.

(*c*) The line looks like an infinitely long line to the source, or "generator" supplying the line.

(*d*) The line is like a pure resistance without reactive effects.

4.99. *Question.* The power input to a 72-ohm concentric transmission line is 5,000 watts. What is the peak voltage between the inner conductor and sheath?

Answer. The peak voltage is 846 volts.

Solution: Apply the power formula to find E, since P and R are given values.

$$P = \frac{E^2}{R}, \quad \text{or} \quad E = \sqrt{PR}$$

Insert the given values and solve; thus

$$E = \sqrt{PR} = \sqrt{5{,}000 \times 72} = \sqrt{360{,}000} = 600 \text{ volts, r.m.s.}$$

To find the peak value, multiply r.m.s. value by 1.41, or

$$E_{\text{peak}} = 600 \times 1.41 = 846 \text{ volts}$$

4.100. *Question.* **A long transmission line delivers 10 kilowatts into an antenna; at the transmitter end the line current is 5 amperes and at the coupling house it is 4.8 amperes. Assuming the line to be properly terminated and the losses in the coupling system negligible, what is the power lost in the line?**

Answer. The power lost in the line is 875 watts.

Solution: With proper line termination the line resistance equals the antenna resistance. Therefore, apply the power formula to find R, or

(1) $$R = \frac{P}{I^2} = \frac{10{,}000}{(4.8)^2} = 435 \text{ ohms}$$

(2) Now find the power at the *input* to the line. Since line I and line R are known,

$$P = I^2R = 5^2 \times 435 = 10{,}875 \text{ watts, input power to line}$$

(3) The power lost in the line equals *power in* minus *power out,* or

$$P_{\text{in}} - P_{\text{out}} = 10{,}875 - 10{,}000 = 875 \text{ watts}$$

4.101. *Question.* **The power input to a 72-ohm concentric line is 5,000 watts. What is the current flowing in it?**

Answer. 8.3 amperes.

Solution: The current is found by applying the power formula, $P = I^2R$, in terms of current, I; thus

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{5{,}000}{72}} = \sqrt{69.44} = 8.3 \text{ amperes}$$

4.102. *Question.* **What is the primary reason for terminating a transmission line in an impedance equal to the characteristic impedance of the line?**

Answer. Proper termination of a transmission line is necessary to eliminate standing waves, that is, to eliminate reflections and prevent radiation from the line, thus reducing losses in the line and effecting a maximum transfer of power to the antenna.

Discussion.

Transmission lines. The usual practice is to employ two conductors or wires to transfer electrical energy from the source or generator to the load. The properties of conductors used for such purposes have been the subject of investigation for many years and it is well known that when the conductors, called "transmission lines," are long they affect the transfer of the a-c energy more than ordinarily would be expected. It was found that if the length of a line approached an appreciable fraction, ⅛ or more, of a wavelength of the a-c signal being passed or transferred, certain unusual properties became evident. The expression "long line" is a relative one which depends upon the application. For example, a telephone line of a few kilometers in length becomes a *long line* or transmission line, whereas, a length of a few meters is a *long line* at high radio frequencies, and a few centimeters constitutes a *long line* at ultra-high frequencies.

A transmission line possesses the properties of inductance, L, and resistance, R, along its length, and capacitance, C, and admittance, G, between the conductors. This statement may be represented pictorially by the diagram in Figure 82. Usually R and G are very small and may be neglected. It is possible to represent this rather involved circuit simply by a resistance, R_0, equal in value to the square root of the ratio of the line inductance to the line capacitance, or in mathematical terms,

$$R_0 = \sqrt{\frac{L}{C}}$$

It has also been found that if the load connected to the end of this line does not equal the resistance, R_0, then "reflections" and "standing waves" will exist. This means that energy traveling down the line will divide at the load, some going into the load and some being reflected back along the line to the source or generator. Such a condition is undesirable, since it means low efficiency and the existence of unexpectedly high voltages at points along the line. For these reasons a transmission line connecting an antenna to a transmitter is always "properly terminated" at the antenna, that is, the antenna coupling circuit is adjusted or tuned so that the antenna seems to have the value R_0 to the transmission line. With the proper adjustment the transmission line and its load look like a simple resistance, R_0, to the transmitter. Therefore, a circuit consisting of a source or transmitter, a transmission line, and an antenna which would be very complex and difficult of analysis if improperly adjusted, becomes quite simple with proper adjustment.

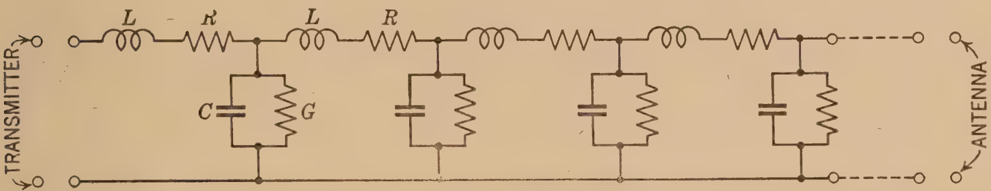


FIG. 82. Equivalent of a transmission line.

Since a transmission line plus antenna are equivalent to a pure resistance the usual problems dealing with such circuits are simplified to a direct application of Ohm's law and the power formula. For example, if the current flowing into a 600-ohm, R_0, line is 5 amperes, the power into the line is 15 kilowatts by the power formula, or $P = I^2R$.

Power Loss in the Transmission Line. It was previously stated that the series resistance along the line usually is negligibly small. This statement is true for the development of the formulas which are approximately true. However, R does have some value and does cause some power loss. In the example just given most of the 15-kilowatt input would be delivered to the antenna, and some of it would be lost in the line. In this example there is still an apparent resistance at the transmitter of 600 ohms and 600 ohms at the terminating or antenna end of the line, but the current at the antenna end will be something less than 5 amperes. Thus, suppose the current at the antenna end of the line is 4.8 amperes, the power to the antenna will be 4.8 squared times 600, or 13.824 kilowatts, so that, evidently, 1.176 kilowatts of energy is lost in the line owing to the resistance.

In present-day antenna systems the transmission lines frequently are "coaxial lines," that is, one conductor is a wire or small pipe and the other is a larger pipe completely surrounding the smaller. The term *coaxial,* or *concentric,* is used because the pipes or conductors have the same center. Such lines are superior electrically to the older type lines consisting of parallel wires because of the greatly diminished importance of temperature and moisture and the fact that the outer conductor may be at ground potential along its length.

The value of R_0 is called by various names, such as, *surge impedance,* or *characteristic impedance,* or *iterative impedance.* It may be calculated for both parallel-wire and concentric lines by the formula

$R_0 = k \log_{10} \frac{b}{a}$, where k = 276 for the open wire line,
b = distance between conductors, center-to-center,
a = radius of a conductor, in the same unit of length as b.
k = 138 for the concentric line,
b = inner radius of the outer conductor,
a = output radius of the inner conductor, in the same unit of length as b,
R_0 = characteristic line impedance in ohms.

4.103. *Question.* In general what type of antenna is most suitable for broadcast stations?

Answer. In general the vertical type radiator is most suitable for broadcast stations. Some stations operate with a ½ wave vertical, or approximately ½ wave, while many use a ¼ wave vertical radiator.

4.104. *Question.* If a vertical antenna has a resistance of 500 ohms and a resistance of zero at its base and antenna power input of 10 kilowatts, what is the peak voltage to ground under 100 per cent modulation?

Answer. 4,465 volts.

Solution: Without modulation the antenna power is 10 kilowatts and therefore at 100 per cent modulation the peak power is 4 times 10 kilowatts, or 40 kilowatts. Apply the power formula in terms of E, where $E = \sqrt{PR}$, and insert the given value for antenna resistance, 500 ohms, and power, 40 kilowatts.

$$E = \sqrt{PR} = \sqrt{40{,}000 \times 500} = \sqrt{20 \times 10^6}$$
$$= \sqrt{20} \times 10^3 = 4.465 \times 10^3 = 4{,}465 \text{ volts}$$

4.105. *Question.* If a vertical antenna 405 feet high is operated at 1,250 kilocycles, what is its physical height, expressed in wavelengths? (One meter equals 3.28 feet.)

Answer. The physical height is 0.516 wavelength. This antenna is approximately a ½ wave vertical radiator.

Solution: This problem requires changing the given values to their equivalents in "meters" and then comparing them. First step is to convert kilocycles to wavelength in meters, thus

$$\lambda = \frac{V}{f}, \quad \text{or} \quad \text{wavelength (meters)} = \frac{300{,}000{,}000 \text{ meters}}{1{,}250{,}000 \text{ cycles}} = 240 \text{ meters}$$

Second step is to convert the given antenna height, 405 feet, into meters and since 1 meter equals 3.28 feet, then

$$\frac{405}{3.28} = 124 \text{ meters, height of antenna}$$

Now compare one wavelength, 240 meters, to the height of the antenna, 124 meters, and we get

$$\frac{124}{240} = 0.516 \text{ wavelength}$$

Note. The equation given above to find wavelength in meters can be expressed in simple form where a number of ciphers appear, as follows:

$$\text{Wavelength (meters)} = \frac{300 \times 10^6}{1.25 \times 10^6} = 240 \text{ meters}$$

4.106. *Question.* **What must be the height of a vertical radiator ½ wavelength high if the operating frequency is 1,100 kilocycles?**

Answer. The height is 448 feet.

Solution: Determine the wavelength for a frequency of 1,100 kilocycles.

$$\text{Wavelength (meters)} = \frac{300 \times 10^6}{1.1 \times 10^6} = 273 \text{ meters}$$

Since the antenna is a 1/2 wave vertical type, its height is

$$\text{height} = \frac{273}{2} = 136.5 \text{ meters, or}$$

$$= 136.5 \times 3.28 = 448 \text{ feet}$$

4.107. *Question.* **Draw a diagram of a crystal oscillator, including temperature control, with one stage of radio-frequency amplification. Power supplies need not be shown, but points at which the various voltages will be connected should be indicated.**

Answer. See Figure 83.

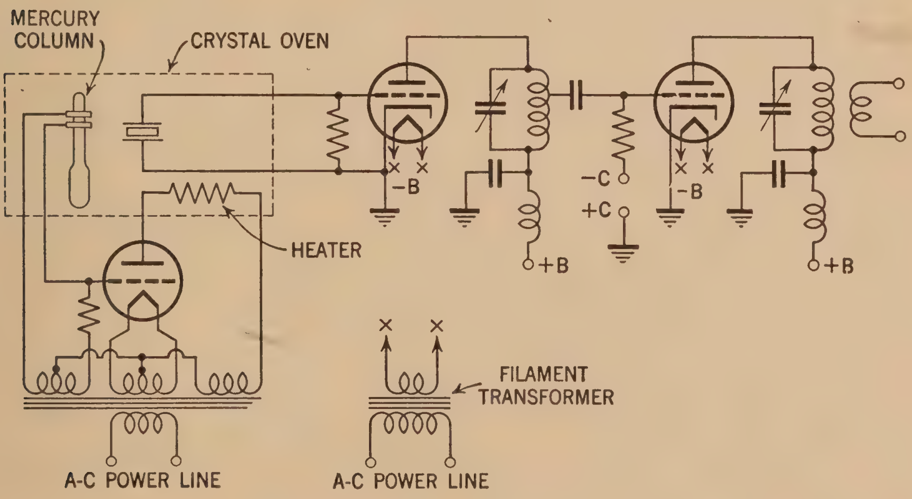


FIG. 83. Temperature control of crystal oven.

4.108. *Question.* **Draw a diagram of a class B push-pull linear amplifier using triode tubes. Include a complete antenna coupling circuit and antenna circuit. Indicate points at which the various voltages will be connected.**

Answer. See Figure 84.

4.109. *Question.* **Draw a diagram of a complete class B modulation system, including the modulated radio-frequency amplifier stage. Indicate points where the various voltages will be connected.**

Answer. See Figure 85.

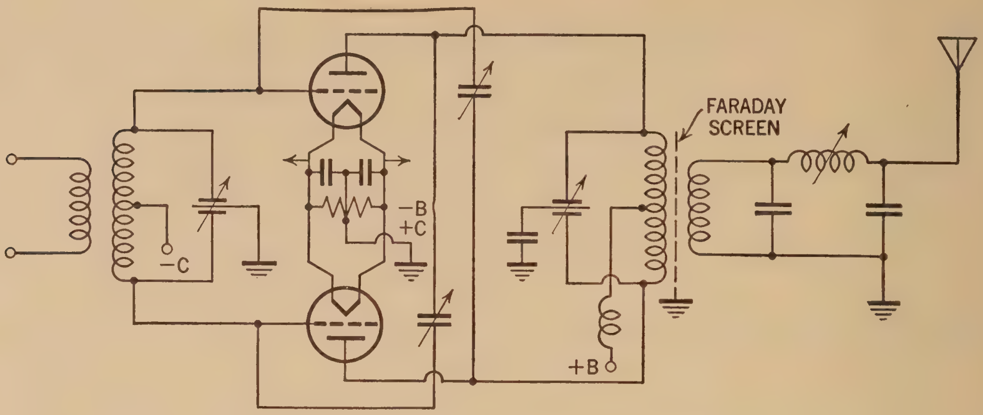


FIG. 84. Power amplifier coupled to antenna.

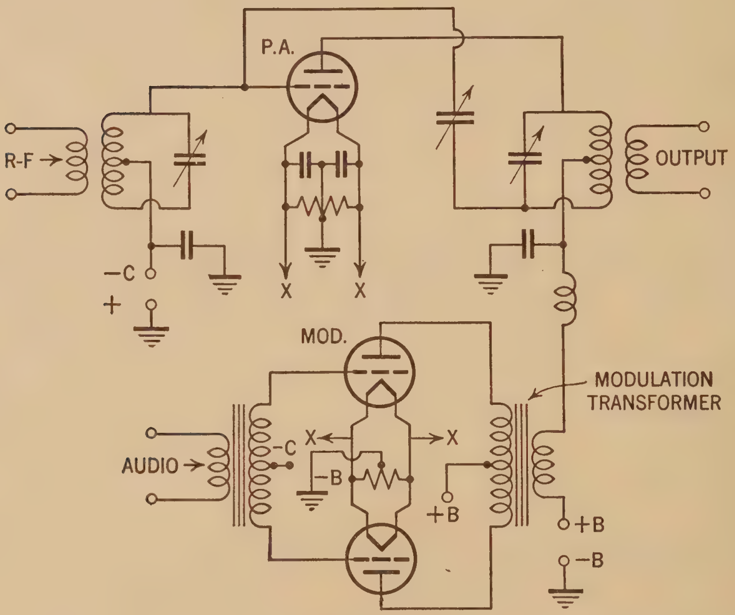


FIG. 85. Complete circuit of a plate-modulated power amplifier.

4.110. *Question.* Draw a simple longitudinal cross section of a water-cooled transmitting triode, showing the internal structure and labeling the various elements.

Answer. See Figure 86.

4.111. *Question.* Show by diagram where the plate ammeter should be connected in a water-cooled triode radio-frequency amplifier with parallel feed in order to exclude the measurement of the leakage current in the water column.

Answer. See Figure 87.

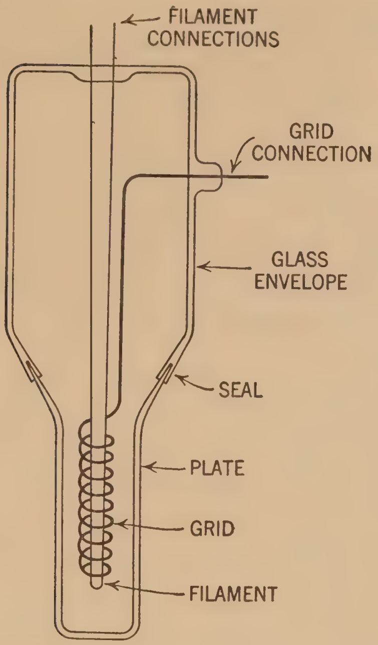


FIG. 86. Simple sketch of a water-cooled tube.

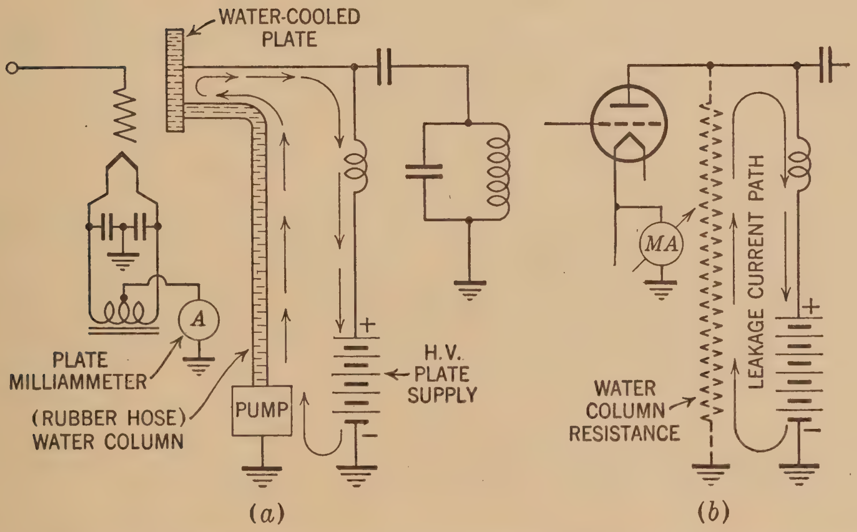


FIG. 87. The plate milliammeter does not indicate leakage current of the water circulation system.

4.112. ***Question.*** **What frequencies are present in the output wave of a transmitter operating on a carrier frequency of 1,100 kilocycles and being modulated by a 400-cycle sinusoidal tone?**

Answer. Three frequencies are present in the output wave, namely, (1) 1,100,400 cycles, the upper side-band frequency, (2) 1,100,000 cycles, the carrier frequency, and (3) 1,099,600 cycles, the lower side-band frequency.

Note. When a carrier is modulated there are additional sum and difference frequencies produced on each side of the carrier. The upper side-band equals the *sum* of the carrier frequency and the modulation frequency, or 1,100,000 + 400, and the lower side-band frequency equals the *difference* between them, or 1,100,000 − 400.

4.113. *Question.* What is a "dummy antenna"?

Answer. A dummy or artificial antenna is a resistive load which may be substituted for the regular antenna at the output of a transmitter to dissipate the power. Such a load is not oscillatory. The use of the dummy antenna allows the transmitter to be adjusted, or tested, or perhaps warmed up prior to normal operation without radiating the carrier which would be a source of interference under such circumstances.

4.114. *Question.* Why are the tubes in the final radio-frequency stages of a transmitter not generally operated as class A?

Answer. The efficiency of class A operation is very low, and, therefore, from the standpoint of economy the final r-f stages should be either class B or class C, preferably class C, for a high-power stage. Where an efficiency of about 50 and 70 per cent might be obtained respectively from class B and class C, an efficiency of only about 25 per cent may be expected from class A. Also, if class A were used in a final stage the tubes required would be relatively large.

4.115. *Question.* A certain transmitter has an output of 100 watts. The efficiency of the final, modulated amplifier stage is 50 per cent. Assuming that the modulator has an efficiency of 66 per cent, what plate input to the modulator is necessary for 100 per cent modulation of this transmitter? Assume that the modulator output is sinusoidal.

Answer. The plate input power to the modulator is 151.5 watts.

Solution: First we notice that if the modulated amplifier has an output of 100 watts and is 50 per cent efficient the input power must be 200 watts. Also, at 100 per cent modulation it is necessary for the modulator to supply an audio power equal to 50 per cent of the input power to the modulated amplifier; hence the audio power **output** is one-half of 200 watts, or 100 watts. But the modulator is only 66 per cent efficient and therefore the **actual** modulator plate **input** is 100 watts divided by the efficiency, or 100/0.66 = 151.5 watts. The last computation is merely applying the formula for efficiency, where

$$\text{Efficiency} = \frac{P_{\text{out}}}{P_{\text{in}}}, \text{ also written as } P_{\text{in}} = \frac{P_{\text{out}}}{\text{efficiency}}$$

Hence,

$$P_{\text{in}} = \frac{100}{0.66} = 151.5 \text{ watts, modulator plate input}$$

4.116. *Question.* If an oscillatory circuit consists of two identical tubes, the grids connected in push-pull and the plates in parallel, what relationship will hold between the input and the output frequencies?

Answer. With this type of connection and with both the grid and plate tanks tuned to the same frequency, there is no change in frequency. However, the plate tank may be tuned to twice the input frequency if desired, and the latter condition suggests the general application for such an amplifier, that is, it has practical use as a frequency doubler.

4.117. *Question.* **Why are series resistors sometimes used in grid circuits of radio-frequency amplifiers?**

Answer. Series resistors are sometimes used for the suppression of parasitic oscillations and to stabilize the amplifier, that is, to prevent self-oscillation in the amplifier.

Discussion. A very small resistor, say about 15 ohms, connected as close as possible to the grid terminal of the socket would suggest that this resistor were being used to suppress parasitic oscillations. If a series resistor of larger size were used, say several hundred ohms, it would act to stabilize the amplifier and prevent self-oscillation at a frequency near the excitation frequency; this is known as the "losser" method of stabilization.

4.118. *Question.* **What may cause "parasitic" oscillations?**

Answer. Parasitic oscillations are caused by the formation of subsidiary oscillatory circuits of very high frequency in a stage due to stray capacity effects between connecting leads and the small inductance which such leads provide. Some practical causes may be due to the wiring of the amplifier where grid and plate leads run more or less parallel, or the leads are too long; separating the leads, changing their relative positions, or shortening connections to grid and plate may sometimes correct this trouble without the use of a parasitic choke or resistor in series with the grid. Parasitics are often troublesome when tubes are connected in push-pull or parallel since such arrangements naturally allow small oscillatory circuits to be formed, which are conducive to the generation of frequencies very much higher than the fundamental frequency of the amplifier.

4.119. *Question.* **What undesirable effects result from overmodulation of a broadcast transmitter?**

Answer. Overmodulation broadens the frequency band, which results in the emission of the transmitter overlapping into adjacent channels and causing serious interference to the services of other broadcast stations. Other undesirable effects are distortion, generation of harmonics, carrier shift, and dynamic instability.

4.120. *Question.* **What do variations in the final amplifier plate current of a transmitter employing low-level modulation usually indicate?**

Answer. Plate current variations in the final stage usually indicate the presence of distortion due perhaps to overloading in the audio system, or excessive r-f excitation, or improper tuning of the tank circuits between the modulated stage and the final stage. With low-level modulation a considerable amount of harmonic distortion will result if the tank circuits carrying the modulated carrier are not accurately tuned to resonance.

4.121. *Question.* **If, upon tuning the plate circuit of a triode r-f amplifier, the grid current undergoes variations, what defect is indicated?**

Answer. Grid current variations while tuning the plate tank of a triode r-f amplifier usually indicate that the stage is incompletely neutralized. Other possible causes are improper operation of the stage resulting from incorrect grid bias, or excessive r-f driving power.

4.122. *Question.* **The 50-kilowatt stage of a broadcast transmitter, having a final amplifier efficiency of 33 per cent, has a plate current of 10 amperes.**

If the water system leakage current meter reads 11 milliamperes, what is the resistance of the water system from plate to ground?

Answer. 1,363,636 ohms.

Solution: Since the plate current, 10 amperes, and the power, 50 kilowatts, are given values the plate voltage can be determined and in turn the resistance can be found by Ohm's law, since the leakage current, 0.011 ampere, is also a given value. However, first find the actual input power since the efficiency is only 33 per cent; thus

$$P_{\text{in}} = \frac{P_{\text{out}}}{\text{efficiency}} = \frac{50{,}000}{0.33} = 150{,}000 \text{ watts}$$

Now apply the watt formula to find volts,

$$E = \frac{W}{I} = \frac{150{,}000}{10} = 15{,}000 \text{ volts}$$

Therefore

$$R = \frac{E}{I} = \frac{15{,}000}{0.011} = 1{,}363{,}636 \text{ ohms}$$

4.123. ***Question.*** **If the final amplifier grid bias supply suddenly became short-circuited in a regular broadcast installation, what would likely result?**

Answer. The loss of grid bias would allow the plate current to rise to an abnormal value, but actually no damage would result because the plate overload relay would trip at some safe limiting value for which it had been set. The opening of the relay removes the plate voltage, or otherwise the tube might be destroyed.

4.124. ***Question.*** **What substance when used as a fire extinguishing agent will subject station personnel to least danger from shock and cause minimum of damage to electrical equipment?**

Answer. Carbon dioxide, CO_2.

4.125. ***Question.*** **What is the primary reason for using chemically pure water in the water cooling system of high-power transmitters?**

Answer. The primary reason for using chemically pure water for cooling high-power tubes is its relatively high resistance; pure water, being a poor conductor, keeps the water leakage current at a minimum, which reduces power losses. If the water were contaminated with foreign matter its resistance would be considerably lower and leakage current would increase with resultant waste of power, since the leakage current serves no useful purpose. Moreover, impure water causes the formation of scale around the sides of the plate, or anode, and water-jacket, which would affect the cooling properties; and in any event the accumulation of scale is a condition to be avoided in a water circulation system.

4.126. ***Question.*** **A 50-kilowatt transmitter employs 6 tubes in push-pull parallel in the final class B linear stage, operating with a 50-kilowatt output and an efficiency of 33 per cent. Assuming that all of the heat radiation is transferred to the water cooling system, what amount of power must be dissipated from each tube?**

Answer. Each tube must dissipate 16,919 kilowatts.

Solution: In this problem the power input should be found so that the power output may be subtracted from it to give the dissipation from the 6 tubes combined, and then ⅙ of this value will give the watt dissipation from each tube.

$$P_{\text{in}} = \frac{P_{\text{out}}}{\text{efficiency}} = \frac{50{,}000}{0.33} = 151{,}515 \text{ watts, power input}$$

$$P_{\text{in}} - P_{\text{out}} = 151{,}515 - 50{,}000 = 101{,}515 \text{ watts, for 6 tubes}$$

or

$$\frac{101{,}515}{6} = 16{,}919 \text{ watts, dissipation from one tube}$$

4.127. ***Question.*** **Draw a simple schematic diagram of the water cooling system of a high-power broadcast station. Assume only one water-cooled stage. Indicate direction of water flow and parts of the system.**

Answer. See Figure 88.

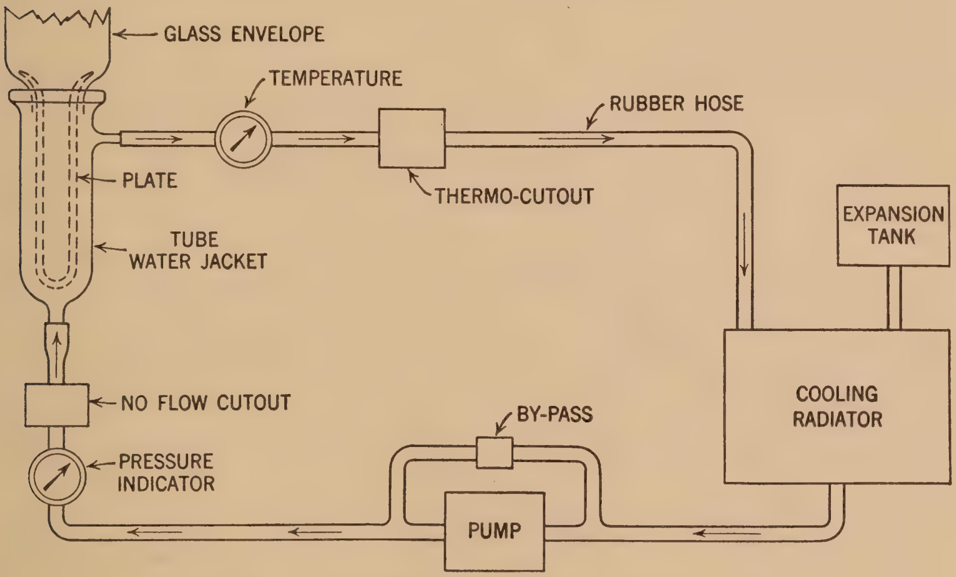


FIG. 88. Component parts of a typical cooling system.

4.128. ***Question.*** **What is the value of voltage drop across the elements of a mercury-vapor rectifier tube under normal conducting conditions?**

Answer. The average voltage drop is 15 volts.

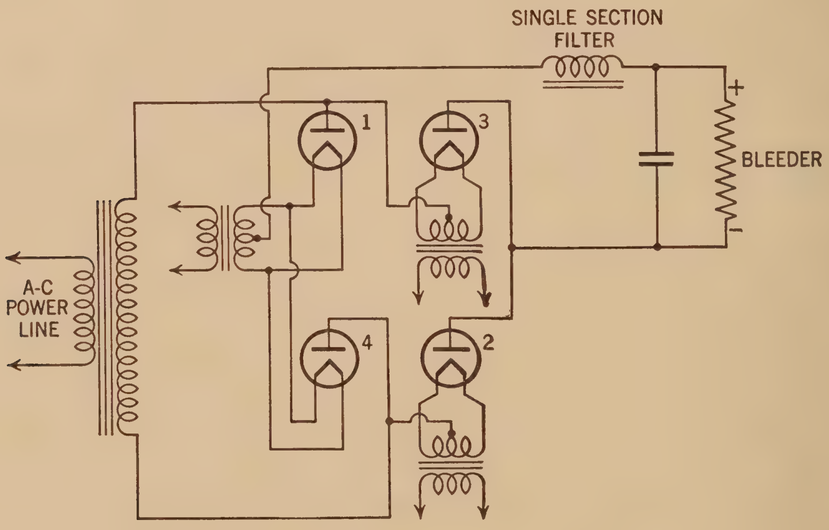
Discussion.

Mercury-vapor rectifier tube. The mercury vapor ionizes at a very low plate potential, a natural characteristic which permits a tube of this type to function differently from tubes that do not contain some form of low-pressure gas. The ionization potential of mercury vapor is 10.4 volts. In this action the atoms of mercury vapor are ionized by the impact of emitted electrons traveling from the hot cathode toward the plate. The electrons freed from the atoms also go to the plate, but the atoms which are deficient in electrons, now called *ions,* quickly migrate toward the cathode to take on sufficient electrons to neutralize their own positive charge. In other words, the *negative space charge* surrounding the cathode is practically neutralized by a *positive space charge,* which these ions represent. With the negative space charge effectively canceled in this way it requires only a very low potential difference between plate and cathode to draw electrons to the plate at practically the same rate they are emitted. Including the voltage drop in the tube's electrodes, a plate potential of about 15 volts is sufficient to provide any value of plate current within the normal limits and operating temperature of the tube. The maximum plate current obtainable is limited mainly by the electron emission of the cathode and the temperature requirements to prevent over-ionization.

High-vacuum rectifier tube. In this type a large number of electrons remain in the vicinity of the hot cathode to form a *negative space charge,* because there is no gas or mercury vapor present to cause ionization to neutralize this charge. The presence of a negative space charge, or cloud of electrons, surrounding a hot cathode presents an opposition to other electrons which tend to leave the cathode, so that full electron emission cannot be obtained. In order to draw these electrons away from the cathode substantially as fast as they are emitted requires the use of a comparatively high plate potential, which accounts for the high internal voltage drop in a high-vacuum rectifier tube.

4.129. *Question.* Draw a diagram of a bridge rectifier giving full-wave rectification without a center-tapped transformer. Indicate polarity of output terminals.

Answer. See Figure 89.



(*a*)

Fig. 89. Bridge type rectifier.

4.130. *Question.* Draw a diagram of a rectifier system supplying two plate voltages, one approximately twice the other and using one high-voltage transformer with a single center-tapped secondary, and such filament supplies as may be necessary.

Answer. See Figure 90.

4.131. *Question.* What is meant by "arc back" or "flash-back" in a rectifier tube?

Answer. "Arc back" is the condition of breakdown of the normal conduction

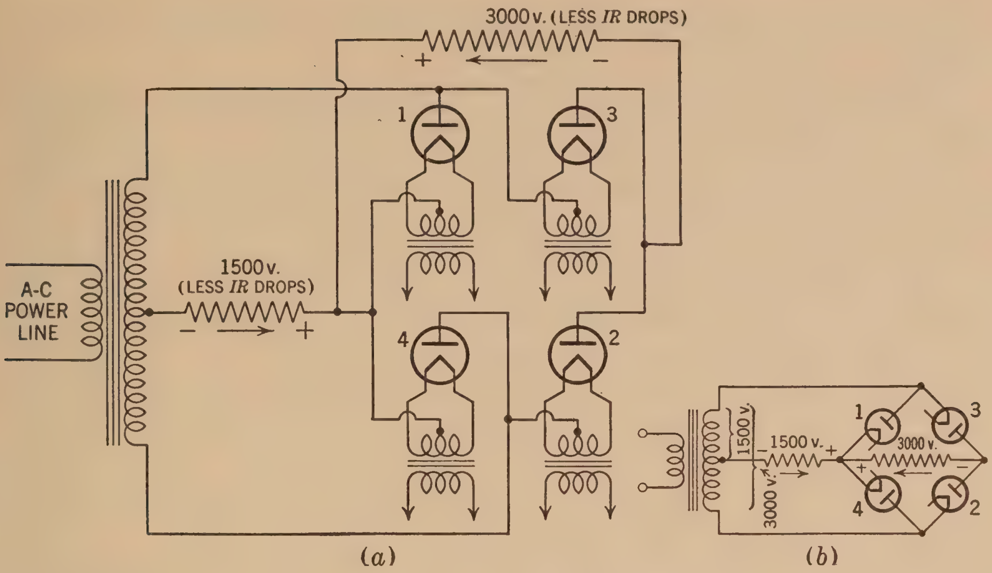


Fig. 90. Two voltages may be obtained from a rectifier using only one power transformer. Both circuits are fundamentally alike; the smaller one (*b*) is a simple arrangement with only cathode symbols, which clearly conveys the principle.

path in a rectifier tube which allows current to flow in the opposite direction to the proper electron conduction in the tube.

Discussion. An excessively high voltage of reversed polarity applied to plate and cathode will cause flash-back and momentarily it is equivalent to a short-circuited condition in the tube. This places a severe strain on other tubes in the rectifier as well as the power supply. Excessive peak voltages developed in a filter might cause this trouble. In a mercury-vapor tube the severe ion bombardment which accompanies arc back might permanently damage the filament. A mercury-vapor tube should not be operated over a specified safe temperature limit because overheating results in increased gas pressure with increased ionization, and a comparatively lower critical peak inverse voltage could then cause flash-back. A high-vacuum rectifier is not so likely to be ruined from an abuse of this kind.

4.132. *Question.* What is meant by the "inverse peak voltage" rating of a rectifier tube?

Answer. The "inverse peak voltage" rating of a rectifier tube is the maximum peak voltage that can be safely applied with reversed polarity on the electrodes from that required for normal direction of electron flow without causing arc back and with the tube operating within specified temperature limits.

4.133. *Question.* What is the principal disadvantage in the use of a dynamotor rather than a motor generator, to furnish power to a small mobile transmitter?

Answer. The principal disadvantage of a dynamotor for this class of service is that it delivers a single voltage which cannot be regulated or changed as would be possible with a motor generator. Since only one field is used in common for both the motor and generator functions any change in the field current would change speed and seriously affect the load-voltage characteristics of the machine. Another disadvantage of a dynamotor is its poor voltage regulation.

4.134. *Question.* How may the output voltage of a dynamotor be regulated?

Answer. There is no practical means for regulating the output voltage of a dynamotor by operation of the machine itself without seriously affecting the load-voltage characteristics. If a lower voltage than normal were desired it could be obtained by the use of a series dropping resistor in the load line at the generator end, or by a lower battery supply voltage.

4.135. *Question.* If a 15-horsepower, 220-volt, single-phase a-c motor is 92 per cent efficient when delivering its full rated output, what is the input current at a power factor of 0.85?

Answer. The input current is 65 amperes.

Solution: The first step calls for finding the power input from the given values for efficiency and rated output in horsepower.

$$P_{\text{in}} = \frac{P_{\text{out}}}{\text{efficiency}} = \frac{15 \text{ h.p.} \times 746}{0.92} = \frac{11{,}190}{0.92} = 12{,}163 \text{ watts, power input}$$

The next step is to apply the power formula, $P = E \times I \times \text{p.f.}$, to determine the current from the given values of voltage and power factor and from the power input just computed.

$$I = \frac{P_{\text{in}}}{E \times \text{p.f.}} = \frac{12{,}163}{220 \times 0.85} = 65 \text{ amperes}$$

4.136. *Question.* How may a condenser be added to a choke input filter system to increase the full-load voltage?

Answer. If the filter were to be kept as a choke-input type there would be no practical way of increasing the full-load voltage by adding a condenser, since the only place for connection would be after the choke. Assuming the filter to be properly designed, the connection of a condenser as just suggested would not give any material improvement. However, if it were permissible to change to a condenser-input type then the added condenser could be connected *before* the choke, that is, at the *input,* with the effect of increasing the full-load voltage. The added condenser at the input of the filter also increases the peak voltage, but the regulation would not be so good as before, since a choke-input system gives better regulation.

4.137. *Question.* Why is it not advisable to operate a filter reactor in excess of its rated current value?

Answer. The filtering action and the regulation which the reactor, or choke, is intended to provide will be impaired because the core will tend to saturate and the inductance of the coil will be lowered. Also, the winding may overheat badly with excessive current passing through it.

4.138. *Question.* What is a "low-pass" filter? A "high-pass" filter?

Answer. A "low-pass" filter is one which passes the low frequencies up to a certain cutoff point and above this all frequencies are attenuated or rejected. A "high-pass" filter is just the opposite in that it attenuates or rejects all frequencies below a certain cutoff point.

4.139. *Question.* Draw a diagram of a simple low-pass filter.

Answer. See Figure 91.

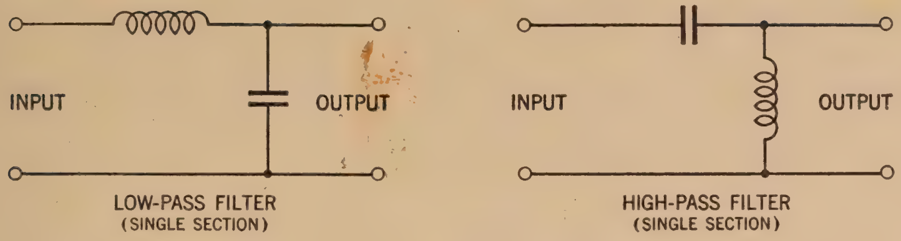


FIG. 91. Low-pass and high-pass filters.

4.140. *Question.* If a power supply has a regulation of 11 per cent when the output voltage at full load is 240 volts, what is the output voltage at no load?

Answer. The output voltage at no load is 269.6 volts.

Solution: Insert the given values in the formula for voltage regulation.

$$\frac{E_{\text{no load}} - E_{\text{full load}}}{E_{\text{no load}}} \times 100 = \text{percentage regulation}$$

In the above formula insert 0.11 for percentage regulation but omit 100, since 11 per cent indicates a ratio of 0.11, and use the given value at full load, 240 volts. Work out as follows:

Let x = no-load voltage

$$\frac{x - 240}{x} = 0.11$$

$$x - 240 = 0.11 \times x \quad \text{(Cross multiplying)}$$

$$x - 0.11x = 240 \quad \text{(Transpose)}$$

$$x(1 - 0.11) = 240 \quad \text{(Factoring } x\text{)}$$

therefore

$$x = \frac{240}{1 - 0.11} = \frac{240}{0.89} = 269.6 \text{ volts}$$

4.141. *Question.* How is the inverse peak voltage to which the tubes of a full-wave rectifier will be subject determined from the known secondary voltages of the power transformer? Explain.

Answer. The inverse peak voltage applied to the tube which is not conducting is the full secondary voltage multiplied by 1.414 and from which value is subtracted both the voltage drop across the conducting tube and the active section of the secondary which is carrying current. The inverse peak voltage is applied across the inactive tube in this way because both tubes in effect are connected in series across the full secondary, since their cathodes are in common and each plate connects, respectively, to opposite ends of the secondary winding. See Figure 41.

4.142. *Question.* If a power supply has an output voltage of 140 volts at no load and the regulation at full load is 15 per cent, what is the output voltage at full load?

Answer. 119 volts.

Solution: This problem is similar in principle to the one in Question 4.140, the difference being that in this case the no-load voltage is a given value. Insert the given values in the percentage regulation formula as follows:

Let x = full-load voltage

$$\frac{140 - x}{140} = 0.15$$

or

$$140 - x = 0.15 \times 140$$

Hence

$$x = 140 - 21 = 119 \text{ volts}$$

Note. The foregoing problem may be solved as follows: The no-load voltage is 140 volts and the regulation is 15 per cent; so then the full-load voltage is 85 per cent (100 – 15) of the no-load voltage, or 85 per cent of 140 volts, hence 140 × 0.85 = 119 volts.

4.143. ***Question.*** **If the secondary of the high-voltage transformer in one phase of a three-phase rectifier system became defective, how could operation be continued until repairs could be made?**

Answer. One means of continuing operation of a three-phase rectifier system under such conditions would be to disconnect the primary of the defective secondary and, if necessary, reduce the drain on the rectifier by operating at a lower voltage.

Another method is to use only two phases in the secondary by disconnecting the line that ordinarily goes to the defective secondary and reconnecting it to the common junction of all the secondaries, assuming that the secondaries are connected in Y (wye).

4.144. ***Question.*** **Why is a time delay relay arranged to apply the high voltage to the anodes of mercury-vapor rectifier tubes some time after the application of filament voltage?**

Answer. The time delay relay is used to protect the filaments of mercury-vapor tubes from possible breakdown by allowing the bulb temperature to become normal; the filaments are given sufficient time to heat up properly for normal emission before applying plate voltage. Also, any condensed mercury formed on the filaments during periods of inoperation of the rectifier will vaporize during the warming up interval.

4.145. ***Question.*** **Why is it important to maintain the operating temperatures of mercury-vapor tubes within specified limits?**

Answer. A mercury-vapor tube functions on the principle of ionization, which makes it quite critical to bulb temperatures which are either too high or too low. A low bulb temperature due to reduced filament voltage lowers the intensity of ionization so that the voltage drop within the tube becomes much greater than is required normally to neutralize the negative space charge; this condition results in overloading, which may ruin the tube. On the other hand, excessive operating temperatures brought on by excessive filament voltage, or perhaps inadequate ventilation, will greatly increase the pressure within the bulb; increased gas pressure intensifies ionization to the point where a lower peak inverse voltage might easily cause flash-back and damage the tube.

4.146. ***Question.*** **If a frequency doubler stage has an input frequency of 1,000 kilocycles, and the plate inductance is 60 microhenrys, what value of plate capacitance is necessary for resonance, neglecting stray capacitances?**

Answer. 105.3 micromicrofarads.

Solution: On the assumption that 1,000 kilocycles is the fundamental frequency and the plate circuit is adjusted to favor the second harmonic, or 2,000 kilocycles, the problem is solved by applying the formula for frequency, or $f = 1/2\pi\sqrt{LC}$, but in terms of capacitance C, as follows:

$$C = \frac{1}{(2\pi f)^2 L}, \quad \text{where } L \text{ is in henrys, } f \text{ is in c.p.s., } C \text{ is in farads.}$$

In the given problem

$$C = \frac{1}{(6.28 \times 2 \times 10^6)^2 \times 60 \times 10^{-6}} = \frac{10^{-6} \times 10^{12}}{39.5 \times 4 \times 60}\ \mu\mu\text{f}$$

or

$$C = \frac{10^6}{39.5 \times 240} = 105.3\ \mu\mu\text{f}$$

4.147. ***Question.*** **Draw a simple schematic diagram of a multivibrator oscillatory circuit.**

Answer. See Figure 92.

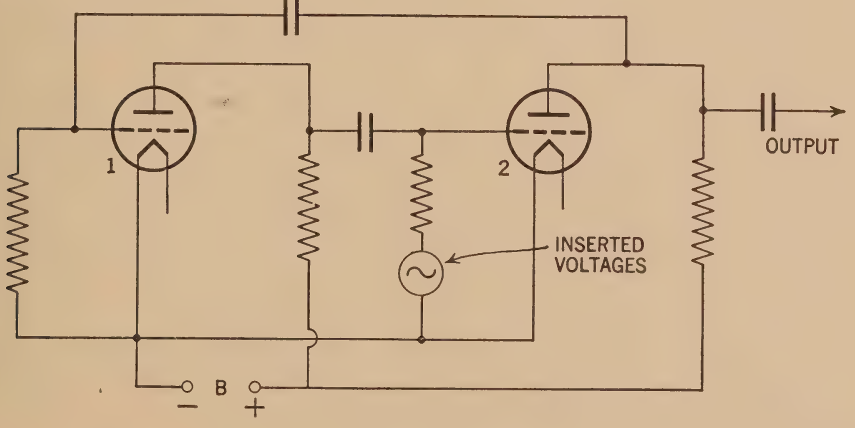


FIG. 92. Multivibrator circuit.

4.148. ***Question.*** **What precautions should be taken to ensure that a crystal oscillator will function at one frequency only?**

Answer. The following precautions should be observed: Maintain the crystal at a constant temperature; operate the crystal with proper r-f feedback voltage; use loose coupling to the following stage to keep circuit reactions at a minimum; employ a buffer stage; do not permit the crystal holder to be subjected to vibrations or jars that would cause the crystal to shift or move in the holder; maintain proper operating voltages; operate the crystal in a circuit having a high "*Q*" at the operating frequency.

4.149. *Question.* What are the advantages of mercury thermostats as compared with bimetallic thermostats?

Answer. In general a mercury thermostat will give greater accuracy and more reliable operation than the bimetallic type. Since the mercury and the contacts are enclosed and do not operate in air there is freedom from the usual troubles encountered when oxidation occurs at exposed contacts which function to make and break an electrical circuit. With contacts operating in a high vacuum, as the length of the mercury column changes, they provide perfect electrical contact over indefinite periods and with increased sensitivity of the make-and-break action. These advantages result in a more uniform temperature coefficient.

4.150. *Question.* A 600-kilocycle X-cut crystal, calibrated at 50° Centigrade, and having a temperature coefficient of -20 parts per million per degree, will oscillate at what frequency when its temperature is 60° Centigrade?

Answer. The crystal will oscillate at 599.8 kilocycles.

Solution: The crystal's temperature is $60 - 50$, or 10° above its calibrated value, and it changes 20 cycles for each degree of temperature change, $10 \times 20 = 200$ cycles; but this means 200 cycles in every million cycles, or megacycle. The calibrated frequency is only 600 kilocycles, or 0.6 megacycle; hence the actual frequency change is 200×0.6, or 120 cycles. In this problem the change is a *negative* one, or -120 cycles because the crystal has a negative temperature coefficient, and therefore the crystal will oscillate at $600{,}000 - 120$, or 599.8 kilocycles. 599.88 KC.

4.151. *Question.* Why are crystals usually operated in temperature-controlled ovens?

Answer. The primary reason is to maintain the best possible frequency stability. When very close frequency tolerances must be observed, such as in broadcast transmitters or in precision measurements, it is necessary to maintain the crystal at a contant temperature to keep the frequency drift within very narrow limits. Where such close frequency tolerances are not required a crystal with a low temperature coefficient could be employed without the use of a temperature-controlled oven.

4.152. *Question.* What is the device called which is used to derive a standard frequency of 10 kilocycles from a standard-frequency oscillator operating on 100 kilocycles?

Answer. Multivibrator.

4.153. *Question.* What procedure should be adopted if it is found necessary to replace a tube in a heterodyne frequency meter?

Answer. The frequency meter should be recalibrated because the interelectrode capacitances of tubes differ somewhat and therefore the circuits tune to different frequencies. With the new tube in place the meter should be warmed up thoroughly and the calibration rechecked by means of zero beats, against a secondary standard or constant frequency oscillator.

Discussion. One type of heterodyne frequency meter includes a piezoelectric calibrator, for checking purposes, the calibrator being a one-megacycle low-temperature-coefficient quartz crystal. With the calibrator several points on each coil range of the heterodyne frequency meter may be checked.

4.154. *Question.* Why is it necessary to employ pure d.c. for the plate supply of a heterodyne frequency meter?

Answer. Reasons for using pure d-c plate supply are to maintain the best possible frequency stability, to provide accurate zero beat indications, and to prevent uncertain zero beat indications which might be caused by harmonics of a poorly filtered plate supply being confused with a multiple of the frequency under measurement. If the d-c plate supply were not steady it would result in modulation of the beat note, and zero beats could not then be accurately checked.

4.155. Question. What are "Lissajous" figures?

Answer. The patterns or wave forms viewed on the fluorescent screen of a cathode-ray tube are known as Lissajous figures. The electron stream within the tube in striking the screen causes a small spot to become luminous. When voltages from different sources are applied to the deflecting plates of the tube the spot traces out a pattern which appears as a line or image, the shape of which depends upon the wave forms of the applied voltages, their frequencies and phase relationships. Although the spot of light is continually moving under the influence of the applied voltages, yet it seems to form a solid line or image before our eyes, this being due to the illusion of persistence of vision; one sees or retains a light spot for a fraction of a second after it disappears or moves to another position while changing its course. These patterns are useful in identifying frequency ratios and the effect of phase shift.

4.156. *Question.* If a frequency of 500 cycles is beat with a frequency of 550 kilocycles, what will be the resultant frequencies?

Answer. The two resultant frequencies are the sum and difference frequencies, or 550,500 cycles and 549,500 cycles.

4.157. *Question.* In what part of a broadcast station system are "phase monitors" sometimes found? What is the function of this instrument?

Answer. A "phase monitor" would be used connected to the line terminating equipment of the antenna system. The function of this instrument is to provide actual measurements of the phase differences of the antenna currents of arrays having two or more elements so that the proper field patterns of multi-antenna systems can be maintained.

With a phase monitor a broadcast transmitter antenna system of this type may be checked to maintain the proper amount of directivity which depends upon the phase of the current in the antenna and in the reflectors. In the operation of certain antenna systems a single radiation pattern is maintained throughout the operating period whereas in other antenna systems more than one radiation pattern would be required at different times.

The input to the phase measuring circuits may be taken from directly across a sampling line connected to a sampling coil which is properly coupled to the antenna element. Sampling lines are usually gas-filled or dried-air lines to offset the effects of humidity which if present might cause variations in the phase measurements. One type of phase monitor is combined with another unit which provides for the remote indication of the amplitude of antenna currents because two such units are most always used together.

4.158. *Question.* If a broadcast station receives a frequency measurement report indicating that the station frequency was 45 cycles low at a certain time, and the transmitter log for the same time shows a measured frequency to be 5 cycles high, what is the error in the station frequency monitor?

Answer. The error is 50 cycles, or the sum of 45 and 5 cycles.

4.159. *Question.* If a heterodyne frequency meter, having a straight-line relation between frequency and dial reading, has a dial reading of 31.7 for a frequency of 1,390 kilocycles and a dial reading of 44.5 for a frequency of 1,400 kilocycles, what is the frequency of the ninth harmonic of the frequency corresponding to a scale reading of 41.2?

Answer. The ninth harmonic frequency is 12,576.8 kilocycles.

Solution: A straight-line or linear relation between frequency and dial reading makes it possible to interpolate in this problem to find the number of cycles covered (frequency spread) by each tenth of a division on the dial scale, or between any two points on the scale.

Proceed as follows: The difference between the two dial readings, $44.5 - 31.7 = 12.8$ divisions, is equivalent to a frequency spread between these two points of $1{,}400 - 1{,}390 = 10$ kilocycles, or 10,000 cycles. Therefore, 10,000 divided by 12.8 gives a spread of 781.2 cycles for each tenth of a scale division. Now take the difference in the number of divisions on the scale between point 44.5 and the new dial reading at point 41.2, which equals 3.3, and multiply 781.2 by 3.3, which equals 2,577.96 cycles, or the frequency spread between these points. Since point 44.5 indicates 1,400,000 cycles, then 3.3 divisions ahead on the scale, or point 41.2, will give 2,577.96 cycles less in frequency, or $1{,}400{,}000 - 2{,}577.96 = 1{,}397{,}423$ cycles. The question asks for the ninth harmonic of this frequency, or $1{,}397{,}423 \times 9 = 12{,}576{,}800$ cycles, or 12,576.8 kilocycles.

4.160. *Question.* What is the reason why certain broadcast station frequency monitors must receive their energy from an unmodulated stage of the transmitter?

Answer. A monitor of the beat-frequency type must receive its energy from an unmodulated stage because it requires a steady beat for accurate monitoring of the carrier frequency. If the modulation frequency were also present it would cause interference with the audio-frequency beat note of the instrument. Instruments of this kind are carefully designed to reduce possible inaccuracy which might be caused by hum modulation of the carrier or other wave form errors. If any program modulation were present in the signal frequency to be checked it would result in undesirable fluctuation of the indicating meter because certain audio components, or those close to the a-f beat tone frequency of the monitor, would effect the metering circuit.

4.161. *Question.* In what part of a broadcast station system are "limiting" devices usually employed? What are their functions?

Answer. Limiting devices are associated with the audio-amplifying system of a broadcast transmitter and in most installations would be part of the speech-input equipment of the transmitter. A limiter is an audio amplifier which is so designed that by adjustment the modulation peaks can be kept down to a given level. This allows a desired percentage of modulation to be maintained without the possibility of overloading or overmodulating on peaks.

4.162. *Question.* What are the results of using an audio-peak limiter?

Answer. The use of an audio-peak limiter permits a higher percentage of modulation to be obtained without the possibility of exceeding this modulation level on peaks, since the limiter can be adjusted to cut down peak amplitudes to a desired value. Other benefits directly due to control of peak amplitudes by adjustment of the limiter circuits are that the modulator stage will not be overloaded on peaks and the carrier will not be interrupted on surges that might otherwise trip overload relays. When a limiter is not used it is necessary to adjust the percentage of modulation for average conditions to a lower level to allow for occasional peaks that come through with the audio signal wave. These audio peaks are not necessary for reproducing a signal and if allowed to go to the modulator stage at their original high amplitude would cause overloading and overmodulation at such moments.

4.163. *Question.* How is the load on a modulator, which modulates the plate circuit of a class C radio-frequency stage, determined?

Answer. The load on a modulator is the d-c resistance of the plate circuit of the modulated class C r-f stage. This resistance, R in ohms, is found by applying Ohm's law where E is the d-c plate voltage applied to the modulated r-f stage and I is the plate direct current in amperes.

$$\text{Load } (R \text{ in ohms}) = \frac{E \text{ (d-c plate voltage of modulated stage)}}{I \text{ (d-c plate current of modulated stage)}}$$

4.164. *Question.* Given a class C amplifier with a plate voltage of 1,000 volts and a plate current of 150 milliamperes which is to be modulated by a class A amplifier with a plate voltage of 2,000 volts, plate current of 200 milliamperes, and a plate impedance of 15,000 ohms. What is the proper turns ratio for the coupling transformer?

Answer. The turns ratio is 2.12 : 1 for the coupling transformer.

Solution: One thing to consider in a problem of this kind is that a class A amplifier should work into a load impedance equal approximately to twice the class A amplifier's own plate impedance to keep the output within certain limits of harmonic distortion. The amplifier's plate impedance, R_p, is its a-c plate resistance. Since this point is not specifically covered in the statement of the problem we will use the recommended value, that is, the load impedance is equal to just twice the class A amplifier's plate impedance. Proceed to solve the problem as follows:

The plate impedance, R_p, of the class A amplifier is given at 15,000 ohms, and twice this value, or 2 R_p, equals 30,000 ohms. Hence, 30,000 ohms is the load impedance into which the class A amplifier will deliver its power, but we find that the actual load, which is the plate d-c resistance of the class C amplifier, is only 6,666.7 ohms. The latter value is determined by applying Ohm's law, where $Z = E/I$, and inserting therein the given values of plate voltage, 1,000 volts, and plate current, 0.150 ampere, or $1{,}000/0.150 = 6{,}666.7$ ohms.

The last step is to apply the formula for determining the turns ratio of the transformer, where Z_1 is the recommended load impedance and Z_2 the actual value.

$$\frac{N_1}{N_2} = \sqrt{\frac{Z_1}{Z_2}}, \quad \text{or} \quad \text{turns ratio} = \sqrt{\frac{30{,}000}{6{,}667}} = \sqrt{4.5} = 2.12 \text{ to 1 step-down ratio.}$$

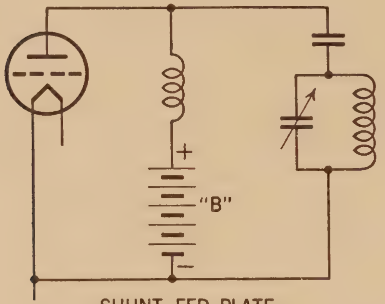
Note. Two values given in the statement of the problem could have been omitted; these values are the plate voltage and plate current of the class A amplifier.

4.165. ***Question.*** **Indicate by a simple diagram the shunt-fed plate circuit of a radio-frequency amplifier.**

Answer. See Figure 93.

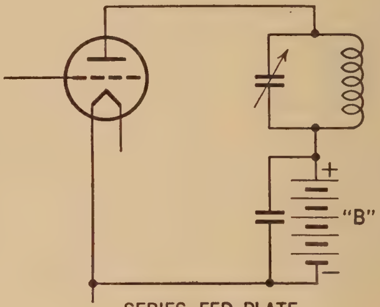
4.166. ***Question.*** **Indicate by a simple diagram the series-fed plate circuit of a radio-frequency amplifier.**

Answer. See Figure 94.



SHUNT-FED PLATE

Fig. 93. The d-c plate supply and plate tank are in shunt with respect to plate and cathode of the tube.



SERIES-FED PLATE

Fig. 94. The d-c plate power supply and plate tank are in series with respect to the plate and cathode of the tube.

4.167. ***Question.*** **With respect to the unmodulated values, doubling the excitation voltage of a class B "linear" radio-frequency amplifier will result in what increase in r-f power output?**

Answer. The r-f power output will be increased four times by doubling the excitation voltage. This relation holds only when a class B amplifier is operated over that portion of the characteristic curve where the amplification is linear. In a class B linear amplifier the power output varies as the square of the grid voltage, or $P_0 = E_g^2$.

4.168. ***Question.*** **At what percentage of modulation does maximum plate dissipation of a class B "linear" amplifier occur?**

Answer. At zero percentage modulation, that is, when no modulation is taking place. In other words, when the plate dissipation is maximum the plate circuit efficiency is lowest which occurs at zero modulation in a class B linear amplifier.

4.169. ***Question.*** **What may be the cause of a decrease in antenna current during modulation of a class B linear radio-frequency amplifier?**

Answer. Downward deflection of the antenna ammeter may be caused by any of the following:

(*a*) Low emission tube or insufficient filament voltage.

If the emission were low it would not permit the plate current changes to reach normal maximum amplitudes on positive peaks of modulation but the plate current could go to zero on negative modulation peaks.

(*b*) Low plate voltage.

An open filter condenser in the plate power supply might cause the plate voltage to be subnormal.

(*c*) Distortion in the audio system.

(*d*) Excessive plate load impedance.

(*e*) Excessive r-f excitation or grid drive.

If the r-f excitation is too great it causes the positive peaks of modulation to be driven into the upper bend of the characteristic where saturation occurs; hence the positive modulation peaks would have less amplitude change than the negative modulation peaks. Excessive r-f excitation would cause the average d-c plate reading to be greater with no modulation applied.

(*f*) Incorrect grid bias voltage.

4.170. *Question.* In adjusting the plate tank circuit of a radio-frequency amplifier should minimum or maximum plate current indicate resonance?

Answer. Minimum plate current, or lowest plate-current dip, indicates resonance.

4.171. *Question.* What is the formula for determining the db loss or gain in a circuit?

Answer. The following three formulas cover the db loss or gain in a circuit in terms of the input and output power ratio, or voltage ratio, or current ratio, providing the input and output impedances are equal. Let N_{db} stand for number of decibels in each formula.

$$\text{Power gain or loss:}\quad N_{\text{db}} = 10 \log_{10} \frac{P_1}{P_2} \tag{1}$$

$$\text{Voltage gain or loss:}\quad N_{\text{db}} = 20 \log_{10} \frac{E_1}{E_2} \tag{2}$$

$$\text{Current gain or loss:}\quad N_{\text{db}} = 20 \log_{10} \frac{I_1}{I_2} \tag{3}$$

4.172. *Question.* What will occur if one tube is removed from a push-pull class A audio-amplifier stage?

Answer. With only one tube in the push-pull stage the second harmonic component will not be canceled in the output and distortion will occur. Also, the absence of one tube may result in further distortion if the core tends to saturate. With only one tube in the stage the hum-frequency level in the plate circuit will be raised.

4.173. *Question.* What is the stage amplification obtained with a single triode operating with the following constants: plate voltage 250 volts, plate current 20 milliamperes, plate impedance 5,000 ohms, load impedance 10,000 ohms, grid bias 4.5 volts, amplification factor 24?

Answer. The stage amplification is 16.

Solution: Only three of the values given in the statement of the problem are needed to find the stage amplification or gain of the stage. These values are

μ = amplification factor,

Z_0 = load impedance,

R_p = plate impedance.

The formula for gain of the stage with computation completed:

$$\text{Gain (stage)} = \frac{\mu \times Z_0}{R_p + Z_0} = \frac{24 \times 10{,}000}{5{,}000 + 10{,}000} = \frac{240{,}000}{15{,}000} = 16$$

4.174. *Question.* Under what circumstances is neutralization of a triode radio-frequency amplifier not required?

Answer. When the stage is operated with low gain or when the stage is used as a frequency multiplier. In the first case there may not be sufficient feedback to cause self-oscillation and in the second case the plate circuit and the grid circuit are not tuned to the same frequency.

4.175. *Question.* Why is it necessary or advisable to remove the plate voltage from the stage being neutralized?

Answer. The accepted practice is to remove the plate voltage because critical neutralizing adjustments then are easier to make than by other methods in which the plate voltage is kept applied. Where plate voltage is applied before initial neutralizing adjustments are made the off-frequency condition of the tank might cause the plate current to become excessively high and damage the tube. Also, it is much safer for the personnel to make adjustments with plate voltage off the stage since high voltages present a hazard at all times.

4.176. *Question.* What is the rule regarding the posting of the station license of a regular broadcast station?

Answer. The station license and any other instrument of authorization or individual order concerning construction of the equipment or the manner of operation of the station shall be posted in a conspicuous place in the room in which the transmitter is located in such manner that all terms thereof are visible. The license of the station operator shall be posted in the same manner. (F.C.C. Rules and Regulations 3.87.)

4.177. *Question.* Under what conditions may a standard broadcast station be operated at a reduced power other than specified in the station license?

Answer. The licensee of a broadcast station shall maintain the operating power of the station within the prescribed limits of the licensed power at all times, except that in an emergency, when, owing to causes beyond the control of the licensee, it becomes impossible to operate with the full licensed power, the station may be operated at reduced power for a period not to exceed 10 days, provided that the Commission and the inspector in charge shall be notified in writing immediately after the emergency develops. (F.C.C. Rules and Regulations 3.57.)

4.178. *Question.* Unless otherwise specified in the license, what type of emission is authorized in all classes of broadcast licenses?

Answer. Type A3 emission.

4.179. *Question.* When the transmitter of a standard broadcast station is operated at 85 per cent modulation, what is the maximum permissible combined audio harmonic output?

Answer. When the transmitter is operated with 85 per cent modulation, not over 10 per cent combined audio-frequency harmonics shall be generated by the transmitter. (F.C.C. Rules and Regulations 3.55.)

4.180. *Question.* What types of standard broadcast stations are permitted to make charges for the transmission of programs?

Answer. Standard broadcast stations and stations in the international broadcast service.

4.181. *Question.* How frequently must the auxiliary transmitter of a regular broadcast station be tested?

Answer. The auxiliary transmitter shall be tested at least once each week to determine that it is in proper operating condition and that it is adjusted to the proper frequency, except that in case of operation in accordance with paragraph (*c*) of this section during any week, the test in that week may be omitted provided the operation under paragraph (*c*) is satisfactory. A record shall be kept of the time and result of each test operating under paragraph (*c*).

Note. The answer to Question 4.182 gives the rule for paragraph (*c*). (F.C.C. Rules and Regulations 3.63.)

4.182. *Question.* For what purpose is an auxiliary transmitter maintained?

Answer. The auxiliary transmitter shall be maintained so that it may be put into immediate operation at any time for the following purposes:

(1) The transmission of the regular programs upon failure of the main transmitter.

(2) The transmission of regular programs during maintenance or modification work on the main transmitter, necessitating discontinuance of its operation for a period not to exceed 5 days. (F.C.C. Rules and Regulations 3.63.)

4.183. *Question.* If the plate ammeter in the last stage of a broadcast transmitter burned out, what should be done?

Answer. No instruments indicating the plate current or plate voltage of the last radio stage, the antenna current, or the transmission line current when logged, in lieu of the antenna current, shall be changed or replaced without written authority of the Commission, except by instruments of the same make, type, maximum scale readings, and accuracy. Requests for authority to change an instrument may be made by letter or telegram giving the manufacturer's name, type number, serial number, and full scale reading of the proposed instrument and the values of current or voltage the instrument will be employed to indicate. Requests for temporary authority to operate without an instrument or with a substitute instrument may be made by letter or telegram stating the necessity therefor and the period involved. (F.C.C. Standards of Good Engineering Practice Concerning Standard Broadcast Stations, Section 3.58.)

4.184. *Question.* What is the frequency tolerance of noncommercial educational broadcast stations?

Answer. The transmitter of each noncommercial educational broadcast station shall be equipped with automatic frequency control apparatus so designed and constructed that it is capable of maintaining the operating frequency within plus or minus 0.01 per cent of the assigned frequency. (F.C.C. Rules and Regulations 4.134.)

4.185. *Question.* Under what circumstances does a radiotelephone first-class license grant authority to the operator to operate a ship station licensed to use types A3 or A4 emission for communication with coastal telephone stations?

Answer. A radiotelephone first-class license authorizes the holder to use type A3 or A4 emission on ship stations which operate on a power of 100 watts, or less, and use type A3 emission for communication with coastal telephone stations.

4.186. *Question.* The currents in the elements of a directive broadcast antenna must be held to what percentage of their licensed value?

Answer. 5 per cent.

4.187. *Question.* Under what circumstances may a relay broadcast station be used?

Answer. A relay broadcast station is a station licensed to transmit from points where wire facilities are not available, programs for broadcast by one or more broadcast stations, or orders concerning such programs. (F.C.C. Rules and Regulations 4.21.)

4.188. *Question.* What are the permissible tolerances of power of a standard broadcast station?

Answer. Each station shall be operated at all times as near to the authorized power as practicable. However, in order to provide for variations in the power supply or other factors affecting the operating power which would necessitate continual adjustment to keep the operating power exactly the same as the authorized power, the operating power may be permitted to vary **from 5 per cent above to 10 per cent below** the authorized power for periods of short duration. (F.C.C. Standards of Good Engineering Practice Concerning Standard Broadcast Stations, Section 11.)

4.189. *Question.* What is meant by "equipment tests" and "service or program tests" where these are mentioned in the Rules and Regulations of the Commission?

Answer. **Equipment test.** Upon completion of construction of a radio station in exact accordance with the terms of the construction permit, the technical provisions of the application therefor and the rules and regulations governing the class of station concerned and prior to filing of application for license, the permittee is authorized to test the equipment for a period not to exceed 10 days.

Service or program test. When construction and equipment tests are completed in exact accordance with the terms of the construction permit, the technical provisions of the application therefor, and the rules and regulations governing the class of station concerned, and after an application for station license has been filed with the Commission showing the transmitter to be in satisfactory operating condition, the permittee is authorized to conduct service or program tests in exact accordance with the terms of the construction permit for a period not to exceed 30 days. (F.C.C. Rules and Regulations, Rules 2.42 and 2.43.)

4.190. *Question.* Name four required entries in the operating log of a standard broadcast station.

Answer. Entries required in the operating log:

(1) The time the station begins to supply power to the antenna, and the time it stops.

(2) The time the program begins and ends.

(3) Each interruption to the carrier wave, its cause and duration.

(4) An entry of the following each 30 minutes:

(*a*) Operating constants of last radio stage (total plate current and plate voltage.)
(*b*) Antenna current.
(*c*) Frequency monitor reading.
(*d*) Temperature of crystal control chamber if thermometer is used.

(F.C.C. Rules and Regulations 3.404.)

4.191. *Question.* At broadcast stations using the direct method of computing output power, at what point in the antenna system must the antenna current be measured?

Answer. The antenna current must be measured at the point where the antenna resistance is measured.

4.192. *Question.* For what purpose may a standard broadcast station which is licensed to operate daytime or specified hours operate during the experimental period without specific authorization?

Answer. The hours between midnight and 6 a.m. cover the experimental period of a standard broadcast station and these hours may be used for testing purposes for proper maintenance of the station but not for regular broadcasting; the tests must be conducted without causing interference to the regular service of other stations which maintain regular schedules during these hours. (F.C.C. Rules and Regulations 3.72.)

Note. Stations involved in the after-midnight frequency monitoring programs are notified of their operating and silent schedule.

4.193. *Question.* What is the allowable frequency deviation, in percentage, for a broadcast station operating on 1,000 kilocycles?

Answer. The allowable frequency deviation is 0.002 per cent. Since the allowable frequency deviation for a broadcast station is within 20 cycles of the assigned frequency, the percentage of deviation for 1,000 kilocycles is

$$\frac{20}{1{,}000{,}000} \times 100 = 0.002 \text{ per cent}$$

4.194. *Question.* What is the last audio-frequency amplifier stage which modulates the radio-frequency stage termed?

Answer. Modulator stage.

4.195. *Question.* How frequently must a remote reading ammeter be checked against a regular antenna ammeter?

Answer. At least once each week.

4.196. *Question.* What factors enter into the determination of power of a broadcast station which employs the indirect method of measurement?

Answer. In accordance with the following formula the factors are the total plate current and plate voltage of the last radio stage and the proper factor, *F*, according to the type of modulation used. (The proper efficiency factor, *F*, is obtained from the table issued by F.C.C.)

$$\text{Operating power} = E_p \times I_p \times F$$

Note. Examples of the use of the efficiency factor, *F*, are: for stations employing plate modulation in the last radio stage *F* ranges from 0.70 to 0.80; for stations of all powers using low-level modulation it ranges from 0.35 to 0.65; for stations of all powers employing grid modulation in the last radio stage it ranges from 0.25 to 0.35. (F.C.C. Rules and Regulations 3.52.)

4.197. *Question.* What is the power that is actually transmitted by a standard broadcast station termed?

Answer. "Operating power" means the power that is actually supplied to the radio station antenna.

4.198. *Question.* Are the antenna current, plate current, etc., as used in the Rules and Regulations of the Commission modulated or unmodulated values?

Answer. Unmodulated values.

4.199. *Question.* With reference to broadcast stations, what is meant by the "experimental period"?

Answer. The experimental period means that time between 12 midnight and 6 a.m. when tests may be conducted for the proper maintenance of a station, providing no interference is caused to the regular service of other stations and compliance is made with the Commission's rule in Section 3.10, Part 3.

Note. The rule referred to in Section 3.10, Part 3, reads as follows: The licensee of each standard broadcast station shall operate or refrain from operating its station during the experimental period as directed by the Commission in order to facilitate frequency measurement or the determination of interference. (Stations involved in the after-midnight frequency monitoring programs are notified of their operating and silent schedule.)

4.200. *Question.* What is the rule governing the posting of the operator license?

Answer. The original license of each station operator shall be posted at the place where he is on duty or kept in his possession in the manner specified in the regulations governing the class of station concerned. (F.C.C. Rules and Regulations 2.52.)

4.201. *Question.* What percentage of modulation capability is required of a standard broadcast station?

Answer. 85 per cent.

Note. F.C.C. Rules and Regulations 3.55*c*, read as follows: The operating percentage of modulation of all stations shall be maintained as high as possible consistent with good quality of transmission and good broadcast practice and in no case less than 85 per cent on peaks of frequent recurrence during any selection which is normally transmitted at the highest level of the program under consideration.

4.202. *Question.* Under what circumstances may radiotelegraph code be transmitted over a broadcast station?

Answer. The following gives several circumstances under which radiotelegraph code may be used over a broadcast station:

(1) Any station which becomes aware that a mobile station is in distress may transmit the distress message when directed to do so by the station in control of distress traffic or when it has reason to believe that a distress call which it has intercepted has not been received by any station in a position to render aid.

(2) All classes of broadcast licenses authorize A3 emission only unless otherwise specified in the license. In case A1, A2, A4, A5, or special emission are necessary or helpful in carrying on any phases of experimentation, application setting out fully the needs shall be made to, and authority therefor received from, the Commission.

(3) During a period of emergency in which normal communication facilities are disrupted as a result of a hurricane, flood, earthquake, or similar disaster.

(4) Code may be used for sound effects as part of a regular broadcast program. (F.C.C. Rules and Regulations 2.61, 4.7, and 2.63.)

4.203. *Question.* Define the maximum rated carrier power of a broadcast station transmitter.

Answer. Maximum rated carrier power is the maximum power at which the transmitter can be operated satisfactorily and is determined by the design of the transmitter and the type and number of vacuum tubes used in the last radio stage. (F.C.C. Rules and Regulations 2.19.)

4.204. *Question.* Define the plate input power of a broadcast station transmitter.

Answer. The plate input power is the product of the plate d-c voltage and the total plate direct current of the last radio stage with no modulation. (F.C.C. Rules and Regulations 3.52.)

4.205. *Question.* Define high-level and low-level modulation.

Answer. "High-level" modulation is modulation produced in the last radio stage of the system. "Low-level" modulation is modulation produced in an earlier stage than the final.

4.206. *Question.* What is the tolerance that is applied to the antenna currents in the various elements of a directional array?

Answer. 5 per cent. (F.C.C. Standards of Good Engineering Practice, Section 12.)

4.207. *Question.* What is the frequency tolerance which must be maintained at the present time by a standard broadcast station?

Answer. A broadcast transmitter must maintain its frequency within 20 cycles of the assigned frequency.

4.208. *Question.* What services may be rendered by a portable transmitter operating in the frequency band 550 to 1,500 kilocycles?

Answer. In the standard broadcast band, a portable transmitter may be used in making field intensity measurements for locating a transmitter site for a broadcast station. A portable broadcast station is not licensed in the standard broadcast band for regular transmission of programs intended to be received by the public.

Note. The term *portable transmitter* means a transmitter so constructed that it may be moved about conveniently from place to place and is in fact so moved about from time to time, but it is not ordinarily used while in motion. (F.C.C. Rules and Regulations 3.13.)

4.209. *Question.* Name three technical changes in a standard broadcast station transmitter which cannot be made without the authority of the Commission.

Answer. No licensee shall change, in the last radio stage, (1) the number of vacuum tubes to vacuum tubes of different power rating or (2) class of operation, nor (3) shall it change the system of modulation without the authority of the Commission.

Note. Rules regarding other technical changes are: No broadcast station licensee shall change the physical height of the transmitting antenna, or supporting structures, or make any changes in the radiating system which will measurably alter the radiation patterns, except upon the written application to and authority from the Commission. (F.C.C. Rules and Regulations 3.43 and 3.45.)

4.210. *Question.* Describe the adjustments which would be necessary to be made to the final amplifier stage of a broadcast transmitter to reduce the power output to one-half that previously being delivered if low-level modulation is used. If high-level modulation is used.

Answer. Adjustments necessary to operate on half-power include the following:

Low-level Modulation.

Operating voltages and excitation. The power output of the last radio stage is reduced by lowering the plate voltage and grid bias voltage and also lowering the excitation in the correct proportion to give the desired r-f current for operation on the lower power.

Antenna and tuning adjustments. After the required changes in voltage and excitation have been made the plate tank circuit of the final stage and the antenna should be carefully retuned and adjusted.

High-level Modulation.

Operating voltage changes. The final radio stage and modulator must both be reduced in power by lowering plate voltage and bias voltage.

Grid excitation. Make adjustments in grid excitation so that any increase in excitation causes no further increase in plate current (plate saturation).

Antenna coupling. Reduce antenna coupling to provide proper load impedance for linearity of the amplifier and power output with good efficiency.

Retuning adjustments. To correct any circuit conditions that may have been altered by these changes, retune tank circuit for minimum plate-current dip and tune the antenna to resonance. Repeat tuning for closer adjustments by first adjusting the antenna coupling and then tuning to provide operation at half power.

Audio adjustments. The foregoing voltage changes will effect the percentage modulation and this will need to be adjusted. The modulation power may be reduced by means of fixed pad attenuators, arranged in steps, through which the audio input from the line is coupled to the terminals of the input audio transformer. A sine wave modulating signal (pure tone of audio frequency) would be used for this purpose and the audio gain adjusted to give the same percentage of modulation as before reducing the power.

4.211. *Question.* What is the frequency tolerance allowed an international broadcast station?

Answer. 0.005 per cent.

4.212. *Question.* What is the required full-scale accuracy of the ammeters and voltmeters associated with the final radio stage of a broadcast transmitter?

Answer. 2 per cent.

4.213. *Question.* Name and define the various classes of emissions which may be radiated by a radio transmitter.

Answer. The emissions classified as types A and B are as follows:

(1) Continuous waves:

Type A0.	Waves the successive oscillations of which are identical under fixed conditions.
Type A1.	Telegraphy on pure continuous waves. A continuous wave which is keyed according to a telegraph code.
Type A2.	Modulated telegraphy. A carrier wave modulated at one or more audible frequencies; the audible frequency or frequencies or their combination with the carrier wave being keyed according to a telegraph code.
Type A3.	Telephony. Waves resulting from the modulation of a carrier wave by frequencies corresponding to the voice, music, or to other sounds.
Type A4.	Facsimile. Waves resulting from the modulation of a carrier wave by frequencies produced at the time of the scanning of a fixed image with a view to its reproduction in a permanent form.
Type A5.	Television. Waves resulting from the modulation of a carrier wave by frequencies produced at the time of the scanning of fixed or moving objects.

(2) Damped waves:

Type B.	Waves composed of successive series of oscillations the amplitude of which, after attaining a maximum, decrease gradually, the wave trains being keyed according to a telegraph code.

Note. Emissions are classified in Article 5, General Radiocommunication Regulations, Revision of Cairo, 1938.

4.214. *Question.* If a broadcast transmitter employs seven tubes of a particular type, how many spare tubes of the same type are required to be kept on hand in accordance with F.C.C. regulations?

Answer. 3 spare tubes.

Note. The requirements regarding spare tubes are covered in the F.C.C. Standards of Good Engineering Practice, as follows: A spare tube of every type employed in the transmitter and frequency and modulation monitors shall be kept on hand. When more than one tube of any type is employed, the following table determines the number of spares of that type required:

Number of each type employed	Spares required
1 or 2	1
3 to 5	2
6 to 8	3
9 or more	4

4.215. ***Question.*** **Describe the various methods by which a broadcast station may compute its operating power, and state the conditions under which each method may be employed.**

Answer. The direct and indirect measurements of operating power are applied as follows:

Direct measurement of operating power.

How determined: The antenna input power determined by direct measurement is the square of the antenna current times the antenna resistance at the point where the current is measured and at the operating frequency.

Conditions governing use: Direct measurement of the antenna input power will be accepted as the operating power of the station provided the data on the antenna resistance measurements are submitted under oath giving detailed description of the method used and the data taken. The antenna current shall be measured by an ammeter of accepted accuracy. These data must be submitted to and approved by the Commission before any license will be authorized to operate by this method of power determination. The antenna ammeter shall not be changed to one of different type, maximum reading, or accuracy without the authority of the Commission. If any change is made in the antenna system, or any change made which may affect the antenna system, the method of determining operating power shall be changed immediately to the indirect method.

Indirect measurement of operating power.

How determined: The operating power determined by indirect measurement from the plate input power of the last radio stage is the product of the plate voltage (E_p), the total plate current of the last radio stage (I_p), and the proper factor (F) according to the type of modulation used, or

$$\text{Operating power} = E_p \times I_p \times F$$

Examples of the range of the efficiency factor, F, are: for stations employing plate modulation in the last radio stage F ranges from 0.70 to 0.80; for stations of all powers using low-level modulation it ranges from 0.35 to 0.65; for stations of all powers employing grid modulation in the last radio stage it ranges from 0.25 to 0.35. (The efficiency factor, F, tables are given in F.C.C. Rules and Regulations 3.52.)

Conditions governing use: The indirect measurement is used only on a temporary basis in an emergency where the licensed antenna has been damaged or destroyed by storm or other cause beyond control of the licensee or pending completion of authorized changes in the antenna system.

4.216. ***Question.*** **What portion of the scale of an antenna ammeter having a square law scale is considered as having acceptable accuracy for use at a broadcast station?**

Answer. The portion from one-third to full scale, that is, the upper two-thirds of the scale.

Note. Section 13 of the F.C.C. Standards of Good Engineering Practice in regard to the antenna ammeter scale reads: No scale division above one-third full scale reading (in amperes) shall be greater than one-thirtieth of the full-scale reading. (Example: An ammeter having a full-scale reading of 6 amperes is acceptable for reading currents from 2 to 6 amperes, provided no scale division between 2 and 6 amperes is greater than one-thirtieth of 6 amperes, or 0.2 ampere.)

4.217. ***Question.*** **Define: Amplifier gain, percentage deviation, stage amplification, and percentage of modulation. Explain how each is determined.**

Answer. **Amplifier gain.** Amplifier gain may be defined as the ratio of the output to input signal voltage or power. It is determined by measurement of the input and output signal voltages of the amplifier, the gain being obtained by dividing the output voltage by the input voltage. Amplifier gain or signal voltage ratio of output to input is expressed in db gain.

Percentage deviation. Percentage deviation is the amount of change from a standard value expressed in percentage. It is determined by taking the amount of the deviation and dividing this amount into the standard value and then multiplying by 100 to express the deviation in percentage.

Stage amplification. Stage amplification and amplifier gain are similar so far as expressing the ratio of output to input signal voltage, with the exception that stage amplification takes into account only a single stage whereas amplifier gain might compare the ratio of signal voltage or power of one amplifier to another. Stage amplification is determined by taking the ratio of the output and input signal voltage of the entire stage, which includes the tube or tubes within the stage as well as the input and output coupling units of the stage.

Percentage of modulation. Percentage of modulation with respect to an amplitude modulated wave means the ratio of half the difference between the maximum and minimum amplitudes of the amplitude modulated wave to the average amplitude, expressed in percentage. An approved modulation monitor, required in all standard broadcast stations, includes an indicating meter which is calibrated for modulation from 0 to 110 per cent and in decibels below 100 per cent with 100 per cent being 0 db. The meter is a d-c meter for setting the average rectified carrier at a specific value and to indicate changes in carrier intensity during modulation. Other instruments capable of determining percentage of modulation are the cathode-ray oscilloscope and vacuum-tube voltmeter, or voltage operated devices which do not absorb power of the signal energy under measurement.

4.218. ***Question.*** **Define an auxiliary broadcast transmitter and state the conditions under which it may be used.**

Answer. The term "auxiliary transmitter" means a transmitter maintained only for transmitting the regular programs of a station in case of failure of the main transmitter.

The auxiliary transmitter shall be maintained so that it may be put into immediate operation at any time for the following purposes:

(1) The transmission of the regular programs upon the failure of the main transmitter.

(2) The transmission of regular programs during maintenance or modification work on the main transmitter, necessitating discontinuance of its operation for a period not to exceed 5 days.

(3) Upon request by a duly authorized representative of the Commission. (F.C.C. Rules and Regulations 3.14 and 3.63.)

4.219. *Question.* **What is the purpose of using a frequency standard or service independent of the transmitter frequency monitor or control?**

Answer. An independent frequency standard provides a positive means of determining that the transmitter's frequency is being maintained within the allowable tolerance. The accuracy of the station's frequency monitor can also be determined. It is a rule of the Commission that certain stations make use of an independent means to check the frequency of emission.

4.220. *Question.* **Discuss the characteristics of a modulated class C amplifier.**

Answer. Important characteristics of a modulated class C amplifier are linear operation, high efficiency, and large power output. With proper adjustments of plate tank circuit impedance and grid bias, usually about twice cutoff value, the operation of the stage can be made practically linear. This means that the r.f. in the plate circuit will vary substantially in direct proportion to the plate (modulation) voltage changes. A large r-f driving power is a requirement. The small angle of plate current flow due to the large bias used and the steep plate current pulses which are possible combine to provide high efficiency and large power output.

4.221. *Question.* **What is the purpose of neutralizing a radio-frequency amplifier stage?**

Answer. Neutralizing prevents self-oscillation in a radio-frequency amplifier. Overloading and unstable operation are undesirable effects which may result when an r-f amplifier breaks into oscillation.

4.222. *Question.* **When the authorized nighttime power of a standard broadcast station is different from the daytime power and the operating power is determined by the "indirect" method, which of the efficiency factors established by the F.C.C. rules is used?**

Answer. The efficiency factor for the *maximum* rated carrier power is used.

Note. F.C.C. Rule 3.53 reads: In computing operating power by indirect measurement the above factors shall apply in all cases and no distinction will be recognized owing to the operating power being less than the maximum rated carrier power.

4.223. *Question.* **Describe the technique used in frequency measurements employing a 100-kilocycle oscillator, a 10-kilocycle multivibrator, a heterodyne frequency meter of known accuracy, a suitable receiver, and standard frequency emission.**

Answer. The three-oscillator method for frequency measurements is applied as follows: The receiver is used to pick up the standard frequency emission which is beat against the 100-kilocycle oscillator in the heterodyne frequency meter. The multivibrator is used to give 10-kilocycle separation between 100-kilocycle points according to the results obtained. The beat of the unknown frequency in the receiver is then transferred to the heterodyne frequency meter and is read on the dial by interpolation. Final step is to apply the correction factor of the heterodyne frequency meter to the observed dial reading.

4.224. *Question.* What is the power specified in the instrument of authorization for a standard broadcast station called?

Answer. "Licensed power" or "authorized power."

4.225. *Question.* What is the effect of 10,000-cycle modulation of a standard broadcast station on adjacent channel reception?

Answer. Beats due to heterodyning result in interference and cross-talk.

4.226. *Question.* What system of connections for a three-phase, three-transformer bank will provide maximum secondary voltage?

Answer. The windings are connected "delta" primary and "Y" secondary. (See Question 2.234.)

4.227. *Question.* Draw a diagram and describe the electrical characteristics of an electron-coupled oscillator circuit.

Answer. See Figure 9. In an electron-coupled oscillator the oscillator section of the tube is coupled into the plate circuit load only by means of the electron stream from cathode to plate in the tube. This provides a means of effectively isolating the plate from the oscillatory section so that plate circuit load changes have practically no effect on the tuned circuit constants. An oscillator of this type has excellent frequency stability.

4.228. *Question.* In frequency measurements using the heterodyne "zero beat" method, what is the best ratio of signal e.m.f. to calibrated heterodyne oscillator e.m.f.?

Answer. A ratio of approximately one to ten, where the amplitude of the local oscillation is relatively large to minimize distortion. In linear detection of heterodyne signals the amplitude of the distortion frequencies is greatest when the two components of e.m.f. are of equal size.

ELEMENT 5

RADIOTELEGRAPH

5.1. *Question.* What is the meaning of "ampere turns"?

Answer. "Ampere turns" is a practical term in use for referring to the magnetizing force resulting from a flow of current through the turns of a coil. Ampere turns equals the product of the number of turns, N, and the current flow in amperes, I, or

$$\text{Ampere turns} = N \times I$$

5.2. *Question.* What is the meaning of "electrolyte"? List four types of radio equipment in which it may be used.

Answer. An "electrolyte" is a conducting medium in which the flow of electric current is accompanied by the movement of matter (A.I.E.E. definition).

Practical meaning of electrolyte: An acid or alkaline solution is known as "electrolyte" when its use is associated with an electrical device. Four types of radio equipment which use electrolyte are: (1) Storage cell, (2) electrolytic condenser, (3) electrolytic rectifier, (4) electrolytic detector.

5.3. *Question.* Name at least five pieces of radio equipment which make use of electromagnets.

Answer. (1) Rotating machinery—motors and generators, (2) meters, (3) relays, (4) mechanical rectifiers, (5) reproducing devices—headphones and loudspeakers.

5.4. *Question.* How many watts equal 1 horsepower?

Answer. 746 watts.

5.5 *Question.* What is the meaning of "residual magnetism"?

Answer. Residual magnetism refers to the magnetic lines of force remaining in a substance after the magnetizing force has been removed.

5.6. *Question.* If two 10-watt, 500-ohm resistors are connected in series, what is the total power dissipation capability?

Answer. $10 + 10 = 20$ watts, total power dissipation capability.

5.7. *Question.* A milliammeter with a full scale deflection of 1 milliampere and having an internal resistance of 25 ohms is used to measure an unknown current, by shunting it with a 4-ohm resistance. When the meter reads 0.4 milliampere, what is the actual value of current?

Answer. 2.9 milliamperes.

Solution: The proportion of current in the meter compared to the shunt is $25 \div 4$, or 6.25 times more current in the shunt. The current in the shunt on full-scale deflection is equal to 6.25 times the meter's full-scale current of 1 milliampere, or $6.25 \times 1 = 6.25$ milliamperes. Therefore, on full-scale deflection the total line current equals 7.25 milliamperes, of which 1 milliampere goes to the meter and 6.25 milliamperes to the shunt. If the meter now reads only 0.4 of its full-scale value the current in the line is proportionately less, or $7.25 \times 0.4 = 2.9$ milliamperes.

Alternate method: Another way of working out and stating the above problem is as follows: The current in the shunt is to the current in the meter as the resistance of the meter is to the resistance of the shunt, or

$$\frac{I_s}{I_m} = \frac{R_m}{R_s}$$

By cross multiplying we get

$$I_s \times R_s = I_m \times R_m$$

Insert the given values and let x stand for the current in the shunt, I_s. Then

$$x \times 4 = 1 \times 25$$

or

$$4x = 25$$

and

$$x = \frac{25}{4} = 6.25 \text{ milliamperes, current in shunt.}$$

The total current in the line, I_{total}, on full-scale deflection is the sum of the two currents, I_s and I_m; hence

$$I_{\text{total}} = I_s + I_m = 6.25 + 1 = 7.25 \text{ milliamperes}$$

Therefore, when the meter indicates only 0.4 of full-scale the current in the line, or actual current, is $7.25 \times 0.4 = 2.9$ milliamperes.

5.8. *Question.* If two 10-watt, 500-ohm resistors are connected in parallel, what is the total power dissipation capability?

Answer. $10 + 10 = 20$ watts, total power dissipation capability.

5.9. *Question.* What is the maximum current carrying capacity of a resistor marked "5,000 ohms, 200 watts"?

Answer. 0.2 ampere.

Solution: Apply the watt formula in terms of current, or

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{200}{5{,}000}} = \sqrt{0.04} = 0.2 \text{ ampere}$$

5.10. *Question.* What factors determine the heat generated in a conductor carrying an electric current?

Answer. In accordance with $P = I^2R$, the factors which determine the heat generated in a conductor are the current squared and the resistance. In turn, the resistance depends upon the kind of material and area of the conductor.

5.11. *Question.* Two resistances of 18 and 15 ohms are connected in parallel, and in series with this combination is connected a 36-ohm resistance; in parallel with this total combination a 22-ohm resistance. The total current flowing through the combination is 5 amperes. What is the current value in the 15-ohm resistance?

Answer. The current in the 15-ohm resistance is 0.908 ampere.

Solution: Each combination in turn should be reduced to its effective resistance until the total effective resistance of the circuit is determined. This value and the total current, which is a given value, are then used in Ohm's law to determine the voltage drop across the total circuit. From this voltage drop the current through each resistor may be found as follows:

Resistance of 18- and 15-ohm parallel combination

$$R = \frac{18 \times 15}{18 + 15} = 8.18 \text{ ohms}$$

Resistance of 18- and 15-ohm parallel combination in series with 36 ohms.

$$R = 8.18 + 36 = 44.18 \text{ ohms}$$

Resistance of the above combination, 44.18 ohms, in parallel with 22 ohms,

$$R = \frac{44.18 \times 22}{44.18 + 22} = 14.66 \text{ ohms, total effective resistance}$$

Voltage applied to the total combination of 14.66 ohms,

$$E = I \times R = 5 \times 14.66 = 73.3 \text{ volts}$$

Current flow through the 44.18-ohm combination consisting of the 36 ohms in series with the 18- and 15-ohm parallel branch,

$$I = \frac{E}{R} = \frac{73.3}{44.18} = 1.664 \text{ amperes}$$

Voltage drop across the 18- and 15-ohm parallel combination,

$$E = I \times R = 1.664 \times 8.18 = 13.62 \text{ volts}$$

Current through the 15-ohm resistance,

$$I = \frac{E}{R} = \frac{13.62}{15} = 0.908 \text{ ampere}$$

5.12. *Question.* What method is used to obtain more than one value of voltage from a fixed voltage d-c source?

Answer. A voltage divider or a potentiometer may be connected across the fixed d-c source to take off intermediate values of voltage.

5.13. *Question.* Two resistors are connected in series. The current through these resistors is 3 amperes. Resistance number one has a value of 50 ohms; resistance number two has a voltage drop of 50 volts across its terminals. What is the total impressed e.m.f.?

Answer. The total impressed voltage is 200 volts.

Calculation: The total impressed voltage equals the sum of the separate voltage drops. One of the voltage drops is a given value, or 50 volts, and the other is found by applying Ohm's law, $E = I \times R = 3 \times 50 = 150$ volts; therefore $150 + 50 = 200$ volts.

5.14. ***Question.*** **A circuit is passing a current of 3 amperes. The internal resistance of the source is 2 ohms. The total external resistance is 50 ohms. What is the terminal voltage of the source?**

Answer. The terminal voltage of the source is 150 volts.

Calculation: When the circuit is passing current the terminal voltage of the source is the same (neglecting voltage drop in the wiring) as the voltage drop across the load, or $E = I \times R = 3 \times 50 = 150$ volts. The internal voltage drop of the source is $3 \times 2 = 6$ volts.

5.15. ***Question.*** **A 10,000-ohm 100-watt resistor, a 40,000-ohm 50-watt resistor, and a 5,000-ohm 10-watt resistor are connected in parallel. What is the maximum value of total current through this parallel combination which will not exceed the wattage rating of any of the resistors?**

Answer. The maximum value of total current is 0.0725 ampere.

Calculation: The problem calls for determining the voltage to be applied to the three resistors in parallel so that the current through any resistor will not cause its wattage rating to be exceeded. If the 5,000-ohm resistor is worked at its full rating of 10 watts by applying a certain voltage to its terminals, the other two resistors, being in parallel and having higher resistances and higher wattage ratings, will be worked under their wattage ratings. Proceed to find the current through the 5,000-ohm resistor; thus

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{10}{5{,}000}} = 0.0447 \text{ ampere}$$

The current just determined is used to find the voltage applied to all the resistors in parallel, or

$$E = I \times R = 0.0447 \times 5{,}000 = 223.5 \text{ volts}$$

The currents through the remaining two resistors are

$$I = \frac{E}{R} = \frac{223.5}{10{,}000} = 0.02235 \text{ ampere}$$

and

$$I = \frac{E}{R} = \frac{223.5}{40{,}000} = 0.0055 \text{ ampere}$$

The total current through the parallel combination is

$$I_{\text{total}} = 0.0447 + 0.0223 + 0.0055 = 0.0725 \text{ ampere}$$

5.16. ***Question.*** **What is the ratio of peak to effective voltage values of a sine wave?**

Answer. The ratio is $\frac{1}{0.707}$, or 1.414 to 1.

5.17. ***Question.*** **If a d-c voltmeter is used to measure effective alternating voltages by the use of a bridge type full-wave rectifier of negligible resistance, by what factor must the meter readings be multiplied in order to give corrected readings?**

Answer. The factor 1.11 is used to give corrected meter readings.

Discussion. The meter in a rectifier circuit responds to the d.c. or *average* value of the rectified output. Assuming the wave form sinusoidal and the maximum value, $E_{\max}$, then the reading of the voltmeter for a full-wave rectification is equal to $0.636E_{\max}$; calling this reading V_m,

$$V_m = 0.636E_{\max}$$

but

$$E_{\max} = \sqrt{2}E_{RMS}, \quad \text{where } E_{RMS} = \text{the effective value of voltage,}$$

and

$$V_m = 0.636(\sqrt{2})E_{RMS} = 0.9E_{RMS}$$

or

$$E_{RMS} = \frac{1}{0.9}V_m = 1.11V_m$$

Accordingly, if the meter readings are each multiplied by 1.11, then the resulting values represent the corrected or *RMS* values of the a-c voltage.

5.18. *Question.* By what factor must the voltage of an a-c circuit, as indicated on the scale of an a-c voltmeter, be multiplied in order to obtain the average voltage value?

Answer. An a-c voltmeter gives the effective voltage, and this value must be multiplied by 0.9 to give the average voltage.

5.19. *Question.* By what factor must the voltage of an a-c circuit, as indicated on the scale of an a-c voltmeter, be multiplied in order to obtain the peak value?

Answer. The factor to use is 1.41.

5.20. *Question.* What is the ratio of peak to average value of a sine wave?

Answer. The ratio of peak to average value of a sine wave is $= \frac{1}{0.636}$, or 1.57 to 1. Hence, $E_{\text{peak}} = E_{\text{av}} \times 1.57$.

5.21. *Question.* What is the meaning of the term "phase difference"?

Answer. In an electrical circuit "phase difference" means that the voltage and current do not reach maximum and minimum values at the same instant, or comparing the events over a full cycle of current and voltage, a difference in phase means that certain points on a current wave compared relatively to similar points on a voltage wave are occurring either ahead or behind each other and not at the same instant.

Standard electrical definition of phase difference: The phase difference between two sinusoidal quantities which have the same time period is the fractional part of a period (not greater than one-half) through which the independent variable must be assumed to be advanced with respect to only one of the quantities in order that similar values of the fundamental components of the two quantities shall coincide. (The American Standard Definitions of Electrical Terms, sponsored by the A.I.E.E.)

5.22. *Question.* What is the meaning of the term "leading power factor"?

Answer. A circuit containing only resistance and capacitance is said to have a *leading* power factor because the current leads the resultant voltage. In a circuit of this kind the entire power input is dissipated in the resistance part of the circuit since the condenser does not consume any energy.

5.23. *Question.* The product of the readings of an a-c voltmeter and ammeter in an a-c circuit is called what?

Answer. The product of a-c voltmeter and ammeter readings is called the "apparent power" or "volt-amperes."

5.24. *Question.* In what units is an alternator output ordinarily rated?

Answer. The power output of large alternators is rated in volt-amperes, or kilovolt-amperes. These become watt and kilowatt ratings respectively when the power factor is unity. The watt is used for small a-c machines.

5.25. *Question.* Define "power factor."

Answer. "Power factor" is the ratio of active power to apparent power.

5.26. *Question.* What is the total inductance of two coils, connected in series but without any mutual coupling?

Answer. The total inductance is equal to the sum of the two separate inductances without any mutual coupling.

Discussion. The total inductance of two coils in series with mutual inductance between them is given by $L_{\text{total}} = L_1 + L_2 \pm 2M$. In this case $M = 0$. Therefore $L_{\text{total}} = L_1 + L_2$.

5.27. *Question.* What is the total inductance of two coils, connected in parallel but without any mutual coupling?

Answer. The total inductance of two inductances in parallel is the product of the two inductances divided by their sum, assuming there is no mutual coupling between them.

Discussion. In considering the equivalent inductance of two coils in parallel we will make the assumption that the resistance of the individual coils is negligible in comparison with their reactances X_1 and X_2, that is, their Q values are high. Under these conditions

$$X = \frac{X_1 \times X_2}{X_1 + X_2} = \frac{\omega L_1 \times \omega L_2}{\omega L_1 + \omega L_2} = \omega \frac{L_1 L_2}{L_1 + L_2}$$

but

$$X = \omega L, \quad \text{where } L = \text{equivalent inductance, and } \omega = 2\pi f.$$

Therefore

$$\omega L = \omega \frac{L_1 L_2}{L_1 + L_2}$$

or

$$L = \frac{L_1 L_2}{L_1 + L_2}$$

Hence, the equivalent (or total) inductance of two inductances in parallel is the product over the sum of the individual inductances, assuming there is no mutual between them. Note that if the coils have appreciable resistance the equivalent inductance is not independent of frequency as in the above case.

5.28. *Question.* A series inductance, acting alone in an alternating current circuit, has what properties?

Answer. A series inductance tends to oppose a change in the value of the current which has the effect of decreasing the power factor of the circuit. An inductance causes the current to lag the voltage by 90°. Its resistance to an alternating current is known as inductive reactance, which is measured in ohms. The inductive reactance varies directly with the frequency of the alternating current. A counter e.m.f. is generated in the turns of an inductance by the action of the varying magnetic lines associated with the alternating current.

5.29. *Question.* What is the total reactance of a series a-c circuit containing no resistance but has equal values of inductive and capacitive reactance?

Answer. The total reactance is zero.

Discussion. The total reactance of reactances in series is equal to their algebraic sum. For the case at hand

$$X_{\text{total}} = X_L + X_C$$

Let A = numerical value of each reactance

$$X_L = +A \text{ (inductive)}$$

$$X_C = -A \text{ (capacitive)}$$

Therefore

$$X_{\text{total}} = X_L + X_C = A - A = 0$$

The total reactance is zero, and therefore the circuit is resonant.

5.30. *Question.* What is meant by the "fly-wheel" effect of a tank circuit?

Answer. The expression "fly-wheel effect" refers to a tank circuit receiving excitation from a pulse of plate current and carrying on the oscillation to the next plate current pulse. Since a tank circuit is an oscillatory circuit consisting of inductance and capacity (coil and condenser) it will generate oscillations for a time after being set into excitation. This is because of the transference of energy from electromagnetic form to electrostatic form, and vice versa.

5.31. *Question.* What may be the effects of shielding applied to radio-frequency inductances?

Answer. Shielding a radio-frequency inductance has the effect of reducing the inductance value of the coil, reducing the Q of the coil, and increasing the distributed capacity of the coil with respect to the shield.

5.32. *Question.* What is the effect on the resonant frequency of connecting a capacitance in series with an antenna?

Answer. The resonant frequency is increased by the use of a series capacitance, which has the effect of decreasing the capacitance of the antenna system.

5.33. *Question.* What is the total impedance of a capacitance and inductance having equal values of reactance, when connected in parallel?

Answer. The equivalent impedance is resistive and equal to infinity.

Discussion. When equal but opposite reactances are connected in parallel their total susceptance is equal to zero. This assumes that the resistances unavoidably associated with the coil and condenser are negligible, that is, their Q's are high. Under such conditions the circuit is in resonance and the total reactance is zero.

An interesting practical state of parallel resonance exists in the combination of a coil whose constants are L_e and R_e and the high Q value tuning condenser C. This constitutes the familiar "tank" circuit.

Refer to the tank circuit given in Figure 95

where L_e = effective inductance,
R_e = effective resistance,
C = capacitance.

$$y_0 = g_0 - jb_0 = g_L + g_c - j(b_L + b_c) \quad \text{(general form of admittance)}$$

At resonance

$$b_0 = b_L + b_c = 0 \qquad \text{(net or total susceptance = 0)}$$

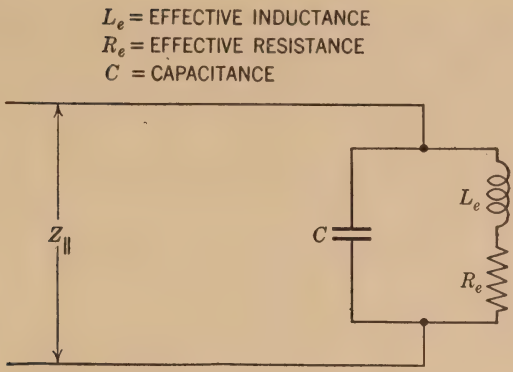


FIG. 95. Problem in a-c circuit theory.

Hence,

$$\begin{aligned} y_0 &= g_0 = g_L + g_c \\ & \qquad\quad \downarrow \qquad \searrow \\ y_0 &= \frac{R_e}{R_e^2 + \omega^2 L_e^2} + 0 \end{aligned}$$

(the total admittance becomes equal to the total conductance at resonance)

Accordingly

$$Z_{\parallel} = \frac{1}{y_0} = \frac{R_e^2 + \omega^2 L_e^2}{R_e} = R_e + \frac{\omega^2 L_e^2}{R_e} \tag{1}$$

$$= R_e + Q\omega L_e$$

where

$$Q = \frac{X_L}{R_e} = \frac{\omega L}{R_e}$$

If the Q is reasonably high

$$Z_{\parallel} = Q\omega L_e = \frac{\omega^2 L_e^2}{R_L} = \frac{L_e}{CR_L} \quad \text{at resonance} \tag{2}$$

Equation 1 for any value of Q and Equation 2 for Q values of the order of 10 or greater give the equivalent parallel impedance at resonance of a coil and condenser combination. In general this equivalent impedance is high, particularly if the Q is high, in which case the values, $Q\omega L_e$ or $\frac{L_e}{CR_L}$, are most conveniently used. At resonance this impedance is resistive and has no X or reactive component. For the ideal case of two equal but opposite reactances as stated in this problem the equivalent impedance is resistive and equal to infinity $\left(Q = \frac{X_L}{R_e} = \infty\right)$ but the reactance is zero.

Note. For additional theory see answers to Questions 3.28, 4.1, and 4.24.

5.34. ***Question.*** What factors determine the efficiency of a power transformer?

Answer. The efficiency of a power transformer depends upon the following factors:

Load; power factor of load.
Extent of principal losses; copper losses, eddy currents, and hysteresis.
Flux density of magnetic circuit; core material and core form.
Leakage reactance of windings.

5.35. ***Question.*** What factors determine the no-load voltage ratio of a power transformer?

Answer. The turns ratio determines the voltage ratio of a power transformer under no-load conditions. The voltages of the primary and secondary are in direct ratio with their respective turns, as given by

$$\frac{E_p}{E_s} = \frac{N_p}{N_s}, \quad \text{where } E = \text{voltage},$$
$$N = \text{number of turns}.$$

5.36. ***Question.*** **What factors determine the ratios of primary and secondary currents in a power transformer?**

Answer. The turns ratio is the principal factor governing the current ratio; the size of the conductors also has some effect on the ratio. The primary and secondary currents are approximately in the inverse ratio of the primary and secondary turns, as given by

$$\frac{I_p}{I_s} = \frac{N_s}{N_p}, \quad \text{where } I = \text{current},$$
$$N = \text{number of turns}.$$

5.37. ***Question.*** **A radio receiver has a power transformer and rectifier designed to supply plate voltage to the vacuum tubes at 250 volts when operating from a 110-volt 60-cycle supply. What will be the effect if this transformer primary is connected to a d-c source?**

Answer. The primary would overheat owing to its low d-c resistance and possibly burn out unless some current overload protection were provided.

5.38. ***Question.*** **What is the relationship between the turns ratio and the impedance ratio of the windings of a transformer?**

Answer. The turns ratio squared is equal to the impedance ratio, as given by

$$\left(\frac{N_p}{N_s}\right)^2 = \frac{Z_p}{Z_s}, \quad \text{or} \quad \frac{N_p}{N_s} = \sqrt{\frac{Z_p}{Z_s}}$$

5.39. ***Question.*** **Why should the cathode of an indirectly heated type of vacuum tube be maintained at nearly the same potential as the heater circuit?**

Answer. The cathode and the heater wire are spaced relatively close, and a condition of voltage breakdown between them causing electron leakage from the cathode is a remote possibility when they are operated at nearly the same potential.

5.40. ***Question.*** **Why is it impracticable to reactivate oxide-coated filament vacuum tubes?**

Answer. The operation of the tube depends upon the emission properties of the oxide coating and when this is lost or weakened through use there is nothing to be gained by reactivation since the filament wire itself is inadequate for the purpose.

5.41. ***Question.*** **What types of vacuum tube emitting surfaces respond to reactivation?**

Answer. Thoriated-tungsten filaments because the electron-emitting material is distributed throughout the wire and not merely coated on the surface of the wire.

5.42. ***Question.*** **Describe how reactivation may be accomplished.**

Answer. Thoriated-tungsten filaments are the only kind that may respond to a reactivation treatment, which consists of *flashing* the filament for a brief period to increase the heat and cause greater electron agitation within the material. This is known as diffusion, or boiling out process, and results in many electrons being driven out toward the surface, forming a surface layer which makes these electrons available for emission. While a general method is used for reactivation, yet there is a great variance of opinion regarding the exact values of excess filament voltage and length of time of flashing to be used. One procedure is as follows: Remove all voltages from the tube except the filament voltage and adjust this voltage to three times the normal value. Flash for about 20 to 30 seconds and then follow by operating the filament at a reduced glow for about 30 to 60 minutes with the voltage held at 25 to 40 per cent above normal. This severe treatment may burn out some filaments so is not always successful.

5.43. *Question.* Is a tungsten filament operated at higher or lower temperatures than a thoriated filament? Why?

Answer. A tungsten filament is operated at a higher temperature than the thoriated type because the electron emission of tungsten at low temperatures is inadequate.

5.44. *Question.* What is indicated when a blue glow is noticed within a vacuum tube envelope?

Answer. A blue glow indicates the presence of gas in the tube.

5.45. *Question.* What is the function of the grid-leak in a "grid-leak type detector"?

Answer. The high-resistance path supplied by the grid-leak through which electrons accumulated at the grid slowly return to cathode results in a negative potential being maintained at the grid which more or less automatically adjusts itself according to the signal and this action keeps the working point at the bend of the E_g—I_p characteristic curve where rectification occurs.

5.46. *Question.* What effect does an incoming signal have upon the value of the plate current of a grid-leak type of detector vacuum tube?

Answer. An incoming signal causes the average change of the plate current to vary below its normal value.

5.47. *Question.* What effect does an incoming signal have upon the value of plate current of a "power" detector tube?

Answer. An incoming signal causes the average change of the plate current to vary above its normal value.

5.48. *Question.* Why is it sometimes necessary to provide a radio-frequency filter in the plate circuit of a detector tube?

Answer. To improve the beat-note reception of telegraph signals when the detector is in an oscillating condition. The filter *C* provides a low reactance path for r.f. between plate and cathode in the detector output; this r-f path is in shunt with the high impedance a-f circuit connected in the tube's output. The filter choke prevents r-f voltages from building up across the audio impedance in the plate circuit.

5.49. *Question.* Explain how "power" detection is accomplished.

Answer. Power detection, or plate detection, requires the use of high plate voltage and the bias adjusted at almost plate-current cutoff value so that the positive half cycles of the signal wave will cause steep plate current pulses, the average of which follows the modulation envelope, or audio component. This average plate current change represents the audio signal, and by working the tube over a long straight portion of its characteristic a reasonably large average above normal value is obtained.

5.50. *Question.* **Explain how "grid-leak" detection is accomplished.**

Answer. A high resistance grid leak is shunted by a condenser of small capacitance, forming an *R-C* combination which is connected to the detector grid. An incoming signal acting across the condenser charges the grid end of the condenser to peak values on the positive half cycles, which causes the grid to accumulate electrons in impulses, known as rectified grid current. The slow rate of flow of electrons returning to the cathode through this high resistance leak results in a voltage drop across the leak and condenser combination which varies with the wave shape of the modulation envelope, or audio component. Since the audio frequencies appear as a separate voltage component on the grid they are amplified in the usual way in passing through the tube. The r-f component in the plate circuit is bypassed from plate to cathode through a condenser. See Question 2.160.

5.51. *Question.* **Explain how "diode" detection is accomplished.**

Answer. The operation is fundamentally one of a rectifier employing two electrodes, plate and cathode. In this circuit the plate current is sent through a resistor, shunted by a condenser, connected in series to the cathode with the plate excitation supplied by the signal current in a tuned r-f circuit connected to the plate and resistor-condenser combination. Plate current flows only on the positive half cycles of the signal so that the condenser charges to peak values during plate current pulses and discharges through the resistor during the negative halves when no plate current is drawn. This action causes the condenser's voltage to vary and follow closely the modulating frequency and amplitude, that is, the audio component of the received signal appears as a voltage at the condenser terminals. This audio voltage is passed along to the grid of the following audio amplifier.

5.52. *Question.* **What is the principal advantage of transformer coupling compared to resistance coupling, as used in audio-frequency amplifiers?**

Answer. A greater gain per stage may be obtained with transformer coupling than with resistance coupling because the voltage ratio of a transformer can be made higher than one to one, whereas with resistance coupling the maximum is one to one.

5.53. *Question.* **Why is it necessary to use two tubes in a class B audio amplifier?**

Answer. Two tubes are required in a class B audio stage to reproduce the full audio cycle, or else serious distortion would result. In class B operation the tubes are biased at cutoff and therefore each tube can amplify only alternate half cycles to produce the full wave in the output.

5.54. *Question.* **What are the advantages of push-pull audio amplification as compared with single-ended amplification?**

Answer. Push-pull operation of an audio stage gives several advantages as follows:

(1) Second and other even harmonics are effectively cancelled.

(2) Saturation of the core of the output transformer is minimized.

(3) Greater undistorted power output.

(4) Less filtering of the power supply is necessary under similar conditions of permissible hum level.

5.55. *Question.* Why is it not feasible to employ a vacuum tube operated class C as an audio amplifier, either singly or in push-pull?

Answer. A highly distorted audio wave shape would result because a full audio cycle cannot be reproduced in the output of an audio stage operated class C since the grids are biased beyond cutoff. The plate circuit of an audio amplifier is not oscillatory, that is, there is no "fly-wheel" effect by which a full cycle might be obtained in the output when the grid receives excitation for less than 180° of the input cycle as in class C operation. A class C amplifier is fundamentally a radio-frequency amplifier.

5.56. *Question.* Why is an audio transformer seldom employed as the output device to be used in the plate circuit of a tetrode audio-amplifier stage?

Answer. The tetrode has inherently a high plate resistance, which makes it difficult to obtain a proper impedance match with an audio transformer. For adequate low-frequency response, the primary open circuit inductance would have to be so high as to be impracticable, or at any rate comparable to that of the secondary, so that for a reasonable band width the step-up would be hardly greater than unity, or 1 : 1.

5.57. *Question.* If a final radio-frequency amplifier, operated as class B linear, were excited to saturation with no modulation, what would be the effect when undergoing modulation?

Answer. Serious distortion would result in both the grid and the plate circuits. When undergoing modulation the positive peaks of the excitation wave would be greatly reduced in amplitude by the voltage drop resulting from the large grid current drawn on these peaks. The plate current pulses would be driven into the region of saturation, causing additional alteration of the wave shape through the flattening of the upward peaks.

5.58. *Question.* Under what "class" of amplification are the vacuum tubes in a linear radio-frequency amplifier stage following a modulated stage operated?

Answer. The stage following the modulated stage is operated class B in order to avoid the introduction of distortion. The stage is preferably operated double-ended. A class B stage using a single tube depends on the "fly-wheel" effect of the tank circuit to insert the half cycle of the signal which is beyond cutoff; the double-ended stage permits each tube to work on a half cycle. However, in either case, single tube or double-ended, the output of a class B r-f stage gives an amplified reproduction of the input wave. A stage operating class A would not be used because of its low efficiency. A stage operating class C, either single tube or double ended, would discriminate against low power frequencies because of the bias beyond cutoff, which would not permit low level signals to cause any plate current flow.

5.59. *Question.* What class of amplifier should be employed in the final amplifier stage of a radiotelegraph transmitter for maximum plate efficiency?

Answer. Class C.

5.60. *Question.* Discuss the effects of insufficient radio-frequency excitation of a class C modulated radio-frequency amplifier in so far as the output signal wave form is concerned.

Answer. The principal effect is serious distortion of the wave shape resulting from flattening of the downward peaks of plate current during the negative halves of the modulation envelope. Other effects are a positive carrier shift and a decrease of antenna current with modulation.

5.61. *Question.* What factors are most important in the operation of a vacuum tube as a frequency doubler?

Answer. In the operation of a frequency doubler it is essential to provide sufficient bias voltage, sufficient driving power or r-f excitation, sufficient plate voltage, and tune the plate tank circuit to twice the frequency of the grid exciting voltage. A bias voltage higher than usual for class C operation, or approximately 2.5 times cutoff, will increase the harmonic output of the doubler. The driving power and plate voltage must be comparatively high, but it is not necessary to operate the tube at the saturation point. A plate circuit tank with a low C value is another factor of importance. This is because a frequency doubler depends upon the fly-wheel effect to carry on the oscillation between short plate-current pulses and a measure of the fly-wheel effect is the ratio of volt-amperes in the tank to the power delivered by the tube.

5.62. *Question.* What is the primary purpose of the suppressor grid of a pentode tube?

Answer. The suppressor grid is used to minimize secondary emission effects, which in turn removes the plate-current limitation of a tube.

5.63. *Question.* What is the primary purpose of the screen grid of a tetrode?

Answer. The primary purpose of the screen grid is to reduce interelectrode capacitance between plate and control grid to a negligible value, which effectively eliminates feedback in the tube.

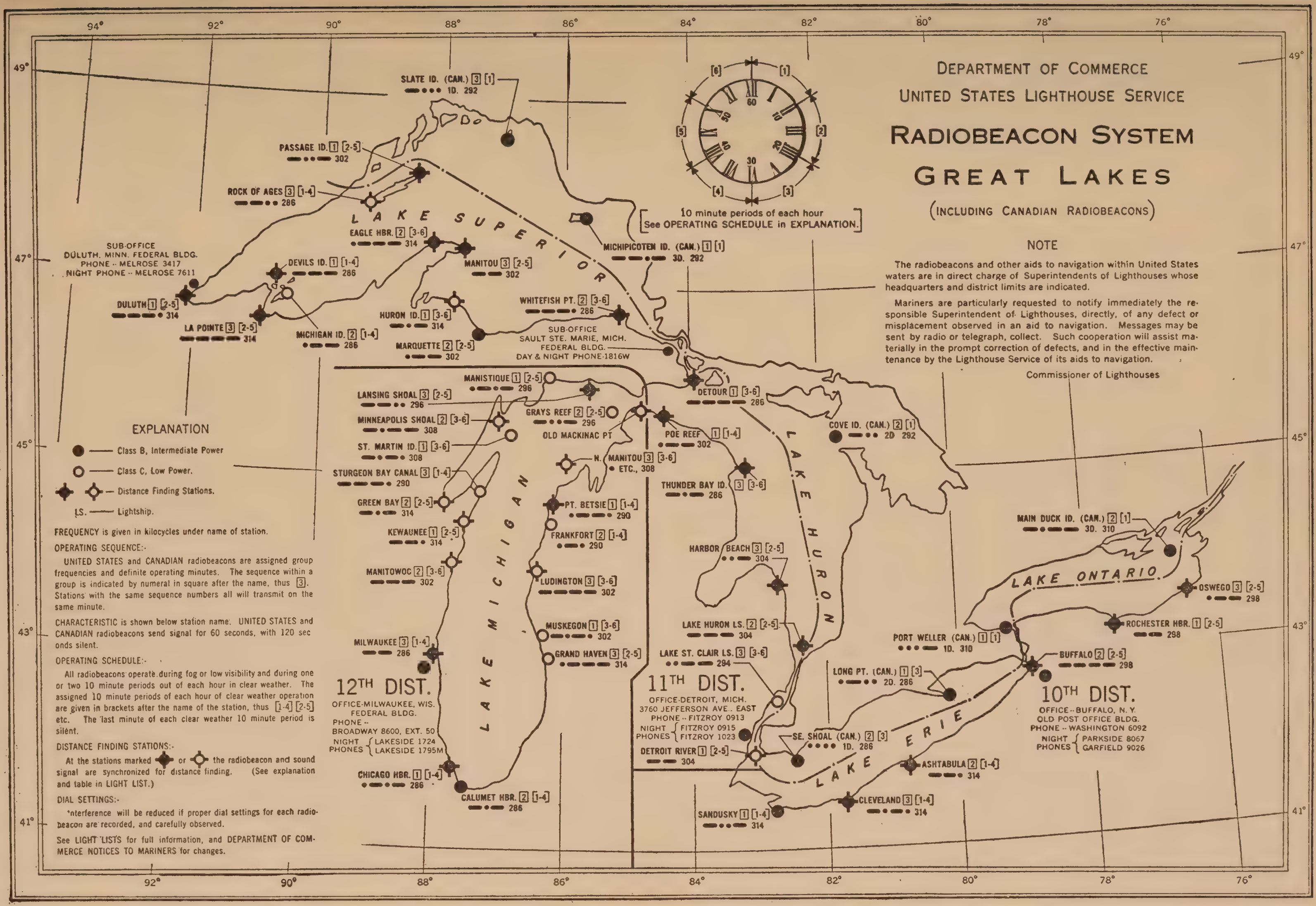
5.64. *Question.* What is the primary purpose of the control grid of a triode?

Answer. The primary purpose of the control grid of a triode is to provide amplification of a signal; the signal voltage is applied to the control grid, which varies a comparatively large amount of plate current.

5.65. *Question.* A triode transmitting tube operates with a plate voltage of 1,250 volts, filament voltage of 10 volts, filament current of 3.25 amperes, and plate current of 150 milliamperes. The amplification factor is 25. What value of control grid bias must be used for operation as a class C stage?

Answer. A bias of approximately −125 volts should be used.

Calculation: Note that several values are given in the statement of the question but only two of them are needed, namely, the plate voltage and amplification factor. However, some



NOTE

The radiobeacons and other aids to navigation within United States waters are in direct charge of Superintendents of Lighthouses whose headquarters and district limits are indicated.

Mariners are particularly requested to notify immediately the responsible Superintendent of Lighthouses, directly, of any defect or misplacement observed in an aid to navigation. Messages may be sent by radio or telegraph, collect. Such cooperation will assist materially in the prompt correction of defects, and in the effective maintenance by the Lighthouse Service of its aids to navigation.

Commissioner of Lighthouses

EXPLANATION

● —— Class B, Intermediate Power
○ —— Class C, Low Power.
✦ ◇ — Distance Finding Stations.
LS. —— Lightship.

FREQUENCY is given in kilocycles under name of station.

OPERATING SEQUENCE:-

UNITED STATES and CANADIAN radiobeacons are assigned group frequencies and definite operating minutes. The sequence within a group is indicated by numeral in square after the name, thus 3. Stations with the same sequence numbers all will transmit on the same minute.

CHARACTERISTIC is shown below station name. UNITED STATES and CANADIAN radiobeacons send signal for 60 seconds, with 120 seconds silent.

OPERATING SCHEDULE:-

All radiobeacons operate during fog or low visibility and during one or two 10 minute periods out of each hour in clear weather. The assigned 10 minute periods of each hour of clear weather operation are given in brackets after the name of the station, thus [1-4] [2-5] etc. The last minute of each clear weather 10 minute period is silent.

DISTANCE FINDING STATIONS:-

At the stations marked ✦ or ◇ the radiobeacon and sound signal are synchronized for distance finding. (See explanation and table in LIGHT LIST.)

DIAL SETTINGS:-

Interference will be reduced if proper dial settings for each radiobeacon are recorded, and carefully observed.

See LIGHT LISTS for full information, and DEPARTMENT OF COMMERCE NOTICES TO MARINERS for changes.

FIG. 96. Radiobeacon system. (*Courtesy of U. S. Lighthouse Service.*)

value of plate-current cutoff is to be approximated for class C operation; let 2½ times cutoff be the recommended value. Applying this factor in the following formula will give the approximate bias voltage, thus

$$-E_g = \frac{E_b}{\mu} \times 2.5 = \frac{1{,}250}{25} \times 2.5 = -125 \text{ volts}$$

5.66. *Question.* **Name four materials which can be used as "crystal" detectors.**

Answer. Galena, silicon, bornite-zincite, and carborundum.

5.67. *Question.* **Why do headphone receivers usually have high impedance windings?**

Answer. Headphone windings usually have a large number of turns (ampere-turns) so that a small current will produce a comparatively large flux to act on the diaphragms. In certain applications, such as in emergency service on shipboard, the headphones must operate on very feeble currents from a simple crystal detector circuit without the benefit of tubes and their amplification. A large number of turns necessarily gives the winding a high impedance. The d-c resistance of high-impedance headphones in most common use is about 2,000 ohms. The high-impedance type of headphones are especially adapted for use directly in the plate circuit of a vacuum tube because in this application they serve not only to reproduce the signal but also to provide the necessary high-impedance load in the plate circuit; the impedance matching requirements with respect to the tube's plate resistance and the load are satisfied sufficiently for all practical purposes.

5.68. *Question.* **What are the objections to the operation of a regenerative, oscillating detector receiver when directly coupled to an antenna?**

Answer. An oscillating detector radiates a wave which may cause interference by heterodyning in the circuits of nearby receivers. In effect a regenerative receiver with its detector oscillating is like a miniature transmitter.

5.69. *Question.* **What controls determine the selectivity of a three-circuit receiver?**

Answer. The selectivity of a three-circuit receiver is governed by the antenna coupling, primary and secondary tuning, and the regeneration control.

5.70. *Question.* **A superheterodyne type receiver is adjusted to 2,738 kilocycles. The intermediate frequency is 475 kilocycles; what is the frequency to which the grid circuit of the second detector must be tuned?**

Answer. 475 kilocycles.

5.71. *Question.* **Explain the reasons why a superheterodyne receiver may not be successfully used for reception of frequencies very near the frequency of the intermediate-frequency amplifier.**

Answer. The receiver used in this way would not discriminate between frequencies close to the intermediate frequency. In effect the receiver would be equivalent to one with several untuned stages of amplification because such signals may be picked up directly on the wiring of the i-f stages.

5.72. *Question.* **A superheterodyne receiver, having an intermediate frequency of 465 kilocycles and tuned to a broadcast station on 1,450 kilocycles,**

is receiving severe interference from an "image" signal. What is the frequency of the interfering station?

Answer. The interfering, or image, frequency is 2,380 kilocycles.

Calculation: On the assumption that the oscillator frequency tracks higher than the desired signal frequency, the oscillator frequency will equal the sum of the desired signal frequency and the intermediate frequency, or $1{,}450 + 465 = 1{,}915$ kilocycles, oscillator frequency. The image frequency is 465 kilocycles above the oscillator frequency, or $1{,}915 + 465 = 2{,}380$ kilocycles, image frequency. In other words, the image frequency is equal to the sum of twice the intermediate frequency and the desired signal frequency, or $(2 \times 465) + 1{,}450 = 930 + 1{,}450 = 2{,}380$ kilocycles, image frequency.

5.73. *Question.* A superheterodyne receiver is tuned to 1,712 kilocycles and the intermediate frequency is 456 kilocycles. What is the frequency of the mixer oscillator?

Answer. 2,168 kilocycles is the mixer oscillator frequency.

Calculation: Assuming the oscillator frequency to track higher than the desired signal frequency, it is only necessary to add the intermediate frequency to the desired signal frequency to find the oscillator frequency, or $456 + 1{,}712 = 2{,}168$ kilocycles.

5.74. *Question.* Describe the "superregenerative" receiver.

Answer. First it is to be mentioned that the main limitation of a regenerative receiver is that during the reception of modulated signals when the regeneration is increased and the gain becomes worth while the detector suddenly breaks into oscillation and destroys the signal. The *superregenerative principle* is to use this tremendous gain by introducing into the grid circuit a second frequency above audibility, which allows the signal oscillations to build up through the high-gain region, stops or quenches them momentarily, and starting over again the action is repeated so fast that the interruptions are unnoticed and only the strongly amplified signal is heard. Therefore, to accomplish this purpose the superregenerative detector oscillates at two widely different frequencies, the quenching frequency and the signal frequency. In one circuit arrangement the detector consists of a tuned grid and plate tickler oscillator circuit working at a superaudible rate, or quenching frequency, say about 30,000 cycles, coupled into an oscillatory circuit working at the signal frequency.

5.75. *Question.* Why are the unused portions of inductances in receivers usually shorted?

Answer. Shorting the unused turns is called "dead-ending" the coil, which is done to minimize losses. Short-circuiting the unused turns prevents the forming of subsidiary resonant circuits.

5.76. *Question.* What is the "mixer" tube in a superheterodyne?

Answer. The mixer tube in a superheterodyne is that tube in which the oscillator frequency and the signal frequency are combined to produce the intermediate frequency. The radio frequency representing the incoming signal is converted to a lower order of frequency, or intermediate frequency, and because of this frequency conversion the *mixer* tube is also known as the *first detector,* or *converter* tube.

Discussion. The input circuit of the mixer tube receives two voltages of different frequencies, the local oscillator voltage and the r-f signal voltage. As these voltages beat, or heterodyne, in the tube a plate current results which contains the two frequencies and in addition numerous other frequencies which represent the sum and difference of the frequencies. The output, or plate circuit, is tuned to select only the beat frequency which is equal to the difference between the oscillator frequency and the signal frequency; this beat frequency is the intermediate frequency.

5.77. *Question.* What is the purpose of a tuned radio-frequency amplifier stage ahead of the mixer stage of a superheterodyne receiver?

Answer. The primary reason for adding a preselector stage ahead of the mixer stage is to eliminate image frequency response. The additional tuned circuits and stage of amplification improve the selectivity and sensitivity of the receiver. Radiation of the local oscillator frequency is prevented by the radio amplifier stage.

5.78. *Question.* What is the advantage of using iron cores of special construction in radio-frequency transformers and inductances?

Answer. The special powdered-iron cores, or cylinders, provide an effective means for adjusting band-width and variable reactance tuning, also called permeability tuning. Tuning of tank circuits may be accomplished without the use of variable condensers, which are possible sources of trouble, especially in marine type transmitters, for example, from accumulation of dust and moisture between plates, shorting of plates, possibility of arc-over, and so on. High-stability fixed mica condensers can be used and the coils tuned by varying the inductance through adjustment of the iron core. Thus, iron core tuning makes it possible to design circuits that mechanically are very compact and without the need of sliding contacts. See answer to Question 6.10.

5.79. *Question.* If signals are heard with the headphones plugged into the detector plate circuit of a receiver but no signals are heard when phones are plugged into the first audio-frequency amplifier stage plate circuit, what might be the cause and how could it be remedied?

Answer. The trouble might be caused by improper contact through the inner leaves of the double-circuit jack in the detector output, or the first a-f transformer may be open-circuited in one of the windings. Other possibilities are a defective audio tube, no audio plate voltage, open circuit conditions from poor contacts in the audio tube socket or phone jack, or open connection to the audio grid bias source. Trouble in the socket or phone jacks should be corrected by cleaning and careful adjustment of spring contacts. A defective transformer should be replaced by an equivalent part; or lacking a transformer, temporary coupling could be improvised if spare high-resistance leaks and a coupling condenser were on hand.

5.80. *Question.* Name three causes of an audio "howl" in a regenerative receiver.

Answer. An audio howl might be caused by an open grid-leak, microphonic tube, excessive regeneration, or plate voltage too high.

5.81. *Question.* Name four reasons which would prevent a regenerative receiver from oscillating.

Answer. Low plate voltage, low filament voltage, low emission tube, reversed tickler coil connections.

5.82. *Question.* What is the advantage of heterodyne reception as compared with autodyne reception?

Answer. Sensitivity is slightly increased in the heterodyne method of beat reception.

5.83. *Question.* How is "automatic volume control" accomplished in a receiver?

Answer. In a system of automatic volume control the circuit is arranged so that the incoming signal after being amplified in the r-f stages is passed through a rectifier (diode) with suitable filters for separating the r-f and a-f components. The rectified radio-frequency current in flowing through a resistor, shunted by a condenser, sets up a d-c voltage which is proportional to the current; the grid returns of the r-f amplifiers connect to the negative potential end of this resistor, and therefore changes of current intensity through it will vary the bias and control the amount of amplification. If the signal level should increase, a larger current flows in the resistor, which increases the bias and lowers the amount of amplification; a reduction of signal strength decreases the bias, which allows a greater amplification. Hence, as the signal goes up or down the change of bias on the r-f stages automatically keeps the volume at a constant level.

5.84. *Question.* What is a "crystal filter" as used in a superheterodyne receiver?

Answer. A filter utilizing the high *Q* properties of a quartz crystal to give the filter circuit very sharp filtering action so that only frequencies very close to the intermediate frequency for which the crystal is ground will pass through to the second detector. The crystal filter is usually connected between the last intermediate-frequency stage and the second detector. It provides a highly selective i-f system advantageous for telegraphic reception, which often requires sharp discrimination against signals close to the desired one; this is commonly called *single-signal* reception.

5.85. *Question.* How may "image response" be minimized in a superheterodyne receiver?

Answer. By the addition of a stage of tuned radio-frequency amplification ahead of the mixer tube.

5.86. *Question.* Discuss the advantages and disadvantages of self-excited oscillator and master-oscillator power-amplifier transmitters.

Answer. The frequency stability of a transmitter is improved by the use of a power amplifier following the master oscillator. This arrangement permits the oscillator to be worked at comparatively low power and the desired output power may be readily obtained by means of one or more r-f amplifier stages. However, the additional parts and tubes mean more circuit adjustments and more sources of possible trouble. A power amplifier stage serves to isolate the oscillator from the antenna so that reactions on the oscillator are reduced to a minimum; for example, reactions such as might be caused by variations in antenna capacitance. In the case of a self-excited type its commercial application is limited practically to emergency radiotelegraph transmitters. Since the oscillator in this type is coupled into the antenna it is subject to heavy plate circuit load changes that may result in serious frequency instability. A few advantages of the self-excited type are less tubes, less parts, and simpler circuits.

5.87. *Question.* **Draw a simple schematic diagram of a dynatron oscillator using a tetrode, indicating polarity of power supply voltages.**

Answer. See Figure 58.

5.88. *Question.* **What is the meaning of "carrier shift"?**

Answer. The expression "carrier shift" refers to a condition of improper operation which causes the positive and negative loops or peaks to become unequal so that the modulation envelope does not then center symmetrically on the carrier frequency. This is regarded as a shift in carrier *amplitude,* not frequency.

5.89. *Question.* **What effect upon the plate current of the final amplifier stage will be observed as the antenna circuit is brought into resonance?**

Answer. The plate current will rise as the antenna is brought into resonance and will read a maximum at resonance.

5.90. *Question.* **What will be the effect of a swinging antenna upon the output of a self-excited oscillator transmitter? A master-oscillator power-amplifier transmitter?**

Answer. The changes in antenna capacitance due to a swinging antenna will cause the oscillator's frequency in the self-excited type to drift over a wide range usually greater than present-day tolerances will permit. A master-oscillator power-amplifier type will have much better frequency stability under such conditions because of the isolation which the power stage provides between the antenna and the master-oscillator.

5.91. *Question.* **Discuss the advantages and disadvantages of operating an amplifier as a class C stage.**

Answer. The main advantages of operating an amplifier class C are high plate-circuit efficiency and high power output. Some of the disadvantages are relatively low power amplification, the need for large driving power, generation of strong harmonics, cannot be used for audio frequencies, cannot be operated as a linear amplifier following a modulated r-f stage.

5.92. *Question.* **What is the crystal frequency of a transmitter having three "doubler" stages and an output frequency of 16,880 kilocycles?**

Answer. The crystal frequency is 2,110 kilocycles. Three doubler stages raise the crystal's frequency 8 times, and $16{,}880 \div 8 = 2{,}110$.

5.93. *Question.* **What is the ratio of the frequencies of the output and input circuits of a single-phase full-wave rectifier?**

Answer. The output frequency is twice the input frequency, or a ratio of 2:1.

5.94. *Question.* **What is meant by "shock" excitation of a circuit?**

Answer. The term "shock" excitation indicates that excitation of large magnitude is applied momentarily to an oscillatory system as a result of which it will generate a wave train of highly damped oscillations.

5.95. *Question.* **What increase in antenna current will be noted when a transmitter is modulated 100 per cent by a sinusoidal audio frequency?**

Answer. 22.6 per cent increase, that is, the antenna current increases 1.226 times over its unmodulated value.

5.96. *Question.* **What may be the reasons why a zero reading is not obtained on the neutralizing indicator while neutralizing a radio-frequency amplifier stage?**

Answer. If a definite minimum r-f indication can be obtained while neutralizing but the r.f. cannot be entirely eliminated to give a zero reading, the difficulty might be due to stray coupling between the amplifier and driver plate tank circuit or to stray capacitances between the component parts of the amplifier, which may unbalance the neutralizing circuit. If a split-stator condenser is used in the tank circuit the ground lead from the rotor to cathode should be as short and direct as possible.

5.97. *Question.* What precautions should be observed in tuning a transmitter?

Answer. Interference with the services of other stations should be avoided; the frequency should be maintained within the allowed tolerance of the assigned frequency; all stages should be properly neutralized; the rated power should not be exceeded; all conditions of operation should be in accordance with the terms of the station license. Specifically, the precautions to observe are to make the initial tuning adjustments on low power, tune and neutralize the individual stages with reduced output coupling, and after the tuning procedure has been completed, the load circuit, either the actual antenna or a dummy antenna, may be coupled to the final stage. Extreme care should be exercised when tuning or making adjustments not to come into contact with high voltage or with a charged condenser after voltage has been removed; make use of a grounding stick to discharge condensers to ground before touching any leads or clips after first removing the high voltage.

5.98. *Question.* Describe a procedure which would be satisfactory in neutralizing a radio-frequency amplifier stage.

Answer. Operate the amplifier normally with excitation applied and with proper filament voltage, but remove the plate voltage by any practical means that will keep the plate r-f circuit intact. Then loosely couple a suitable absorption type r-f indicator to the plate tank coil and proceed to tune the tank to resonance as shown by a maximum indication on the r-f indicator. Follow this by adjusting the neutralizing condenser for a minimum indication on the r-f indicator. These adjustments may have the effect of slightly detuning the driver plate tank, and it should be retuned to resonance as indicated by minimum plate-current dip in the driver stage. Since one adjustment affects another, the amplifier plate tank again should be retuned to resonance, as shown by maximum r-f on the indicator. However, this maximum normally is much less than the previous maximum because with each readjustment the amplifier should approach the neutralized condition, as shown by a gradual decrease of r-f voltage in its plate tank circuit. Again the neutralizing condenser is adjusted to give the lowest r-f indication or, if possible, zero indication. At this step it is necessary to couple the indicator closer because of the smaller r.f. in the tank. After repeating the foregoing steps several times, a setting for the neutralizing condenser is usually found which shows no r.f. on the indicator. When there is no r-f voltage in the plate tank the amplifier is properly neutralized. The final steps are to remove the indicator to prevent burnout, apply plate voltage; and tune the plate tank for minimum plate-current dip.

Alternative method. An alternative method for neutralizing an r-f amplifier is to use the d-c grid meter for the indicator instead of the absorption type coupled to the plate tank. At the start the filament voltage should be adjusted to normal, the plate voltage should be removed but the plate r-f circuit should be kept intact, and the driver stage should be adjusted to give maximum grid current (rectified grid current), which is a measure of the r-f grid excitation. If the stage is unneutralized the grid current reading will flicker or swing widely as the plate tank is tuned back and forth through resonance. The procedure for neutralizing is to slowly adjust the neutralizing condenser while carefully tuning the plate tank back and forth through resonance in order to reduce the amount of flicker on the grid meter until it finally remains steady. With the neutralizing condenser set in this position the grid current goes through a smooth peak showing no change as the plate tank is tuned through resonance, which indicates the amplifier is properly neutralized.

5.99. *Question.* Name three instruments which may be used as indicating devices in neutralizing a radio-frequency amplifier stage of a transmitter.

Answer. Simple types of r-f indicators are a neon bulb, a flashlight bulb, or a thermogalvanometer connected in series with a loop of insulated wire consisting of one or two turns. The more sensitive types are a vacuum-tube voltmeter and a cathode-ray oscilloscope.

5.100. *Question.* Describe a means of reducing sparking at the contacts of a key used with a radiotelegraph transmitter.

Answer. A condenser and resistor in series connected in shunt with the key provide a means for reducing sparking because the condenser absorbs a charge when the key is opened and dissipates it by discharging through the resistor when the key is closed.

5.101. *Question.* How may instruments used to indicate various direct currents and voltages in a transmitter be protected against damage due to stray r-f energy?

Answer. Direct-current instruments may be protected by shunting them with bypass condensers, or in some cases two condensers in series are shunted across a meter with the center lead grounded.

5.102. *Question.* What is the purpose of a "choke" coil?

Answer. The definition explains the purpose: A "choke" coil is a coil of low resistance and sufficient inductance to impede definitely alternating or transient currents as distinguished from direct currents or currents of normal frequency. (A.I.E.E. definition.)

5.103. *Question.* What currents will be indicated by a milliammeter connected between the center-tap of the filament transformr of a tetrode and negative high voltage (ground)?

Answer. The plate and screen grid currents flow through the milliammeter, and if the control grid return lead is grounded any control grid current also will be indicated.

5.104. *Question.* What emergency repairs may be made to an inductance coil having burned or charred insulation?

Answer. The burned or charred insulation should be removed to allow the bare wire to be coated with some insulating material having a low dielectric loss, such as insulating varnish or collodion.

5.105. *Question.* Name five indications of a defective vacuum tube in a transmitter.

Answer. Assuming that all the operating voltages are normal, a defective vacuum tube might be indicated by any of the following: low plate current, low circulating current in the plate tank, low antenna current, blue haze within the envelope, filament open and showing no light.

5.106. *Question.* What is the purpose of an air gap in the core of a filter choke coil?

Answer. The purpose of an air gap is to increase the reluctance of the magnetic path which prevents saturation of the core material by the direct current through the coil.

5.107. *Question.* What are some uses of a "low-pass" filter network?

Answer. A ripple filter is a low-pass filter used in power supply equipment to reduce the ripple current from a rectifier or generator while allowing the free flow of the direct current. Other uses are in selective signaling systems or as limiting filters in telephone lines where the filter must pass a single band of frequencies extending from zero frequency up to some cutoff frequency and substantially attenuate all frequencies above this critical value. Also, low-pass filters are sometimes installed at the input end of a transmission line, to the antenna, in dealing with harmonic suppression.

5.108. *Question.* What is a "swinging" choke?

Answer. A "swinging" choke is an input choke of a power supply filter in which the inductance is increased as the load current falls within specified limits. Hence, as the direct current increases in the coil the inductance decreases and consequently the impedance or c.e.m.f. of the coil goes down. In other words, as the direct current increases the voltage drop across the coil decreases, which tends to stabilize the effect in a filter such as might be used in a class B amplifier power supply. An ordinary choke has an air gap in the core to give it a high reluctance and thus minimize the possibility of core saturation by the direct current passing through the coil. A swinging choke has no air gap, or possibly a very small one, which gives the core a low reluctance and allows some degree of saturation to occur for large values of direct current.

5.109. *Question.* Indicate the approximate values of power supply filter inductances encountered in practice.

Answer. Chokes ranging in value from about 10- to 30-henrys are in most common use.

5.110. *Question.* Why is the core of a transformer made of sheets of iron rather than a solid piece of iron?

Answer. Core laminations are used to minimize losses of energy converted into heat as a result of eddy currents induced in the iron.

5.111. *Question.* What factors determine the eddy-current losses in a transformer?

Answer. The particular kind of magnetic material and thickness of the laminations that compose the core structure.

5.112. *Question.* Name the losses which are present in transformers.

Answer. Hysteresis, eddy-current, and copper losses.

5.113. ***Question.*** **What factors determine the hysteresis losses in a transformer?**

Answer. The frequency of the current and the particular kind of ferromagnetic material used for the core structure.

5.114. ***Question.*** **What is the secondary voltage of a transformer which has a primary voltage of 100, primary turns 200, and secondary turns 40?**

Answer. 20 volts.

Calculation: The primary and secondary voltages are proportional to the primary and secondary turns, or

$$\frac{E_s}{E_p} = \frac{N_s}{N_p} \quad \text{Therefore} \quad E_s = \frac{N_s}{N_p} \times E_p = \frac{40}{200} \times 100 = 20 \text{ volts}$$

5.115. ***Question.*** **Why should emery cloth never be used to clean the commutator of a motor or generator?**

Answer. Emery cloth is a hard abrasive material containing metallic particles which not only tend to scratch or score the commutator but may lodge around the brushes or between the segments and cause short circuit troubles.

5.116. ***Question.*** **When increased output voltage is desired from a motor-generator set, what is the usual procedure?**

Answer. Increase the field current in the generator by reducing resistance at the generator field rheostat. The speed is usually held constant.

5.117. ***Question.*** **What will be the effect(s) of a short circuit in an armature coil of a d-c motor?**

Answer. Overheating, sparking at the commutator, reduction of speed under load.

5.118. ***Question.*** **When starting a d-c motor-generator set what adjustment should be made to the motor field rheostat?**

Answer. The motor field rheostat should be adjusted for minimum resistance to allow full current in the field.

5.119. ***Question.*** **What may be the trouble if a motor generator fails to start when the start button is depressed?**

Answer. No line voltage, blown fuse, button switch defective or out of adjustment, open in main contactor coil of starter, defective contact bar action, insufficient brush contact with commutator, open in motor field, open in motor field rheostat, open in motor armature, open-circuited condition due to disconnected leads.

5.120. ***Question.*** **What load conditions must be satisfied in order to obtain the maximum possible output from any power source?**

Answer. The resistance of the load must equal the internal resistance of the source to obtain maximum output.

5.121. ***Question.*** **Explain the principle of operation of an electrolytic condenser.**

Answer. An electrolytic condenser consists of two electrodes, at least one of which must be a valve metal, separated by an electrolyte. A valve metal is a metal or alloy having properties that cause the formation of a dielectric film adjacent to the surface of the conductor from chemical changes when the passage of current is from metal to electrolyte. The film offers a very high resistance to the current and consequently results in a high-potential drop when current flows in this direction. Hence only a small leakage current flows in the direction of high impedance, but the current flows readily in the other direction. The dielectric film and the two electrodes form a condenser which is polarized.

5.122. *Question.* **Why are "bleeder" resistors used in power supplies?**

Answer. A bleeder resistor protects the filter condensers from breakdown because it keeps a load on the rectifier at all times, which prevents dangerous voltage peaks from developing when the regular load is decreased or removed. Incidentally, the use of a bleeder improves the voltage regulation and also serves as a discharge path for the high-voltage filter condensers for the protection of the personnel after the equipment is shut down.

5.123. *Question.* **Why is a condenser sometimes placed in series with the primary of a power transformer?**

Answer. A series condenser might be used for reducing the secondary voltage. Also, it might be used for regulating current by changing the primary reactance.

5.124. *Question.* **What factors determine the breakdown voltage rating of a condenser?**

Answer. The kind of dielectric and thickness of dielectric (distance between the respective plates).

5.125. *Question.* **What is the effect of low temperatures upon the operation of a lead-acid storage battery?**

Answer. A low temperature may freeze the electrolyte if its specific gravity is low, indicating a partially discharged condition of the battery. Also, low temperatures lessen the activity of the chemical reaction, which results in sluggishness of the battery on discharge.

5.126. *Question.* **Why should the tops of lead-acid storage batteries be kept clean and free from moisture?**

Answer. Moisture on the tops of the jars allows *creepage* between the terminal posts, which slowly discharges the cells. If continued too long this results in lowering the ampere-hour capacity of the battery. Also, the terminal voltage would drop rapidly on load owing to the increased internal resistance of the cells.

5.127. *Question.* **How may the condition of charge of an Edison cell be determined?**

Answer. A d-c voltmeter is used to check the condition of charge of an Edison cell. In large battery banks an ampere-hour meter is usually provided as a general check on the charge and discharge cycles, although for actual check on the individual cells a voltmeter is required.

5.128. *Question.* **What special precautions should be taken when lead-acid storage cells are subject to low temperatures?**

Answer. Lead-acid storage cells should be kept in a charged condition or else the electrolyte is likely to freeze at low temperatures.

5.129. *Question.* **What should be done if the electrolyte in a lead-acid storage cell becomes low owing to evaporation?**

Answer. The electrolyte should be brought up to the proper level covering the plates by the addition of distilled water, or fresh water which has been approved for the purpose.

5.130. *Question.* **What precautions should be used when an absorption type frequency meter is used to measure the output of a self-excited oscillator?**

Answer. The coupling between the pick-up coil of the meter and the oscillator tank should be as loose as practicable, or just sufficient to give a reliable indication. The reactions due to close coupling will alter the oscillator's frequency and cause a large error in the reading.

5.131. *Question.* **What is the meaning of "zero beat" as used in connection with frequency-measuring equipment?**

Answer. Zero beat is a condition wherein two frequencies are in exact agreement and therefore there is no heterodyning action between them. Since the frequency of the oscillator of the frequency meter can be read on a calibrated dial by first beating the meter to zero to place it in calibration, the frequency being measured can also be read on the dial at zero beat. If headphones were used in the output the beat note would disappear at zero beat.

5.132. *Question.* **What precautions should be taken before using heterodyne frequency measuring equipment?**

Answer. A heterodyne-frequency meter should be allowed to warm up thoroughly before it is used. Also, the operating voltages should be normal; and just before using, the meter should be put in calibration by adjusting it for zero beat. Furthermore, only a pure d.c. should be used for plate supply, and the meter should be periodically checked against a calibrated frequency oscillator.

5.133. *Question.* **If a wavemeter, having an error proportional to the frequency, is accurate to 20 cycles when set at 1,000 kilocycles, what is its error when set at 1,250 kilocycles?**

Answer. The error is 25 cycles.

Computation: The error in cycles is proportional to the frequency in kilocycles. Therefore $20 : 1{,}000 :: x : 1{,}250$. Since the product of the means is equal to the product of the extremes, we have

$$1{,}000 \times x = 20 \times 1{,}250$$

$$1{,}000x = 25{,}000$$

$$x = \frac{25{,}000}{1{,}000} = 25 \text{ cycles}$$

5.134. *Question.* **What cleaning agents may be used to clean the surfaces of a quartz crystal? Is such cleaning ever necessary?**

Answer. It is essential that the surfaces of a quartz crystal be scrupulously clean. A speck of dirt or a greasy film on the face of a crystal may change its characteristics entirely. For this reason it is important that a crystal be carefully cleaned after handling with the fingers, and the crystal should be assembled under reasonably dust-free conditions. One of the best cleaning agents is carbon tetrachloride (Carbona).

5.135. *Question.* **Name five advantages of crystal control over tuned circuit oscillators.**

Answer. (1) Greater frequency stability. (2) The small size of the crystal element permits practical use of temperature control to keep the amount of frequency drift within very narrow limits. (3) Easier to adjust to the desired frequency. (4) Greater selectivity is obtained owing to the high *Q* properties of the crystal. (5) The *Q* value of a crystal is many times greater than a coil and condenser assembly of much larger dimensions.

5.136. *Question.* Why is a separate source of power desirable for the crystal oscillator unit of a transmitter?

Answer. A separate source of plate power is desirable in order to operate the crystal oscillator with maximum frequency stability. The separate power supply isolates the oscillator plate circuit from reactions due to modulation and plate circuit load changes in the r-f stages that would result in large distortion and frequency variations.

5.137. *Question.* Why is the temperature of a quartz crystal usually maintained constant?

Answer. The temperature of a quartz crystal is usually maintained constant to keep the amount of frequency drift within very narrow limits. Temperature changes have an effect on the physical dimensions of a crystal which influences the frequency.

5.138. *Question.* What will be the effect of a high degree of coupling between the plate and grid circuits of a quartz crystal oscillator?

Answer. A high degree of coupling between the plate and grid circuits might cause excessive feedback to overload and possibly fracture the crystal; excessive coupling might cause the crystal oscillator to jump to a different frequency.

5.139. *Question.* What is the function of a quartz crystal in a radio transmitter?

Answer. A quartz crystal controls the frequency of oscillation of the master oscillator which is the source of the frequency assigned to the transmitter. The crystal's special properties improve the frequency stability of the transmitter.

5.140. *Question.* What does the expression "a low temperature coefficient crystal" mean?

Answer. A "low temperature coefficient" refers to a crystal being comparatively free from frequency changes with change in temperature.

5.141. *Question.* What does the expression "the temperature coefficient of an X-cut crystal is negative" mean?

Answer. The expression "negative temperature coefficient" means that the frequency increases as the temperature decreases. Crystals of the X-cut type usually have a negative temperature coefficient.

5.142. *Question.* What will be the effect of applying a d-c potential to the opposite plane surfaces of a quartz crystal?

Answer. A crystal with a d-c potential applied to the opposite plane surfaces will undergo a change in its dimensions, that is, it becomes deformed and remains so until the applied voltage is removed. A large d-c voltage would cause great mechanical strain or a maximum of deformation which might crack or shatter the crystal.

5.143. *Question.* What does the expression "the temperature coefficient of a Y-cut crystal is positive" mean?

Answer. The expression "positive temperature coefficient" means that the frequency increases as the temperature rises. For example, in a given Y-cut crystal the frequency may increase 35 to 40 parts in a million for each degree Centigrade of change of temperature.

5.144. *Question.* Draw a simple schematic diagram of a crystal-controlled vacuum tube oscillator using a tetrode type tube. Indicate power supply polarity where necessary.

Answer. See Figure 97.

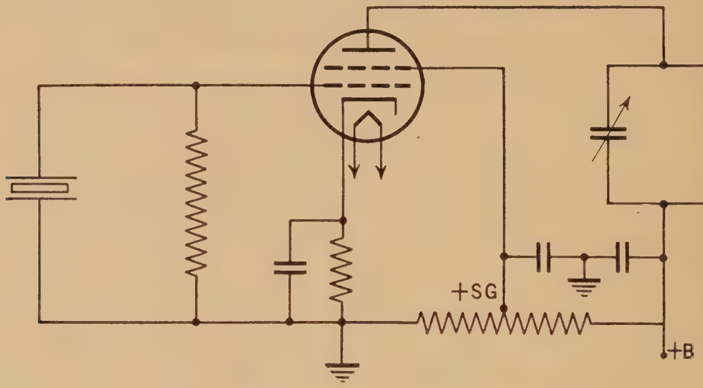


FIG. 97. Crystal oscillator employing a tetrode.

5.145. *Question.* What is a "multivibrator"? Explain its principle of operation.

Answer. A multivibrator is a resistance-capacitance-tuned oscillator. It consists of a two-stage resistance-coupled amplifier with the output feeding back into the input. It operates on the principle that the frequency depends upon the R and C values of the interstage coupling elements, and the 180° phase shift in each tube provides the correct regeneration voltage on the grid of the input tube. (See answer to Question 3.151 for further discussion on a multivibrator.)

5.146. *Question.* What is a dynatron oscillator? Explain its principle of operation.

Answer. A dynatron oscillator is one in which the plate is operated at a critically lower voltage than the grid, or screen grid in a tetrode tube, in order to utilize the effects of secondary emission. The operation of this oscillator requires the screen grid voltage to be adjusted at about twice the plate voltage so that the electrons (secondary electrons) lost to the plate go to the higher positive potential grid. This gives the tube a negative resistance characteristic because increases of plate voltage which intensify secondary emission decrease the plate current whereas decreases of plate voltage which lessen secondary emission effects result in an increase of plate current. The oscillatory circuit, being a positive resistance and connected in the plate, in effect is shunted across the negative resistance tube. When the negative and positive resistances balance, making the net resistance zero, then oscillations start and for a greater negative resistance the amplitude of the oscillations builds up accordingly.

5.147. *Question.* **What is an electron-coupled oscillator? Explain its principle of operation.**

Answer. An electron-coupled oscillator is one in which the control grid, screen grid, and cathode are arranged to form a triode oscillator with the plate or output taking no part in the generation of the oscillations; the screen grid takes the place of the plate's usual function in a triode oscillator. It operates on the principle that the triode section generates the oscillations and the flow of electrons from cathode to plate results in a plate current containing the frequency of the oscillator circuit. Hence, the oscillator section of the tube is coupled into the plate circuit load only by means of the electron stream from cathode to plate in the tube. This provides a means of effectively isolating the plate from the oscillator section so that plate circuit load changes have little practical effect on the tuned circuit constants. An oscillator of this type has excellent frequency stability.

5.148. *Question.* **Explain the principle of generation of radio-frequency energy by means of a spark discharge.**

Answer. See the answer to Question 3.146.

5.149. *Question.* **Explain the principle of generation of radio-frequency energy by means of an electric arc.**

Answer. See answer to Question 3.147.

5.150. *Question.* **Draw a simple schematic diagram of a crystal-controlled oscillator and means of coupling to the following radio-frequency amplifier, showing power supply polarities.**

Answer. See Figure 6.

5.151. *Question.* **Draw a simple schematic diagram of an oscillatory circuit involving the use of a spark gap discharge, indicating the circuit elements necessary to identify this form of oscillatory circuit.**

Answer. See Figure 59.

5.152. *Question.* **Draw a simple schematic diagram of an electron-coupled oscillator, indicating the circuit elements necessary to identify this form of oscillatory circuit.**

Answer. See Figure 9.

5.153. *Question.* **Draw a simple schematic diagram of a dynatron type of oscillator, indicating the circuit elements necessary to identify this form of oscillatory circuit.**

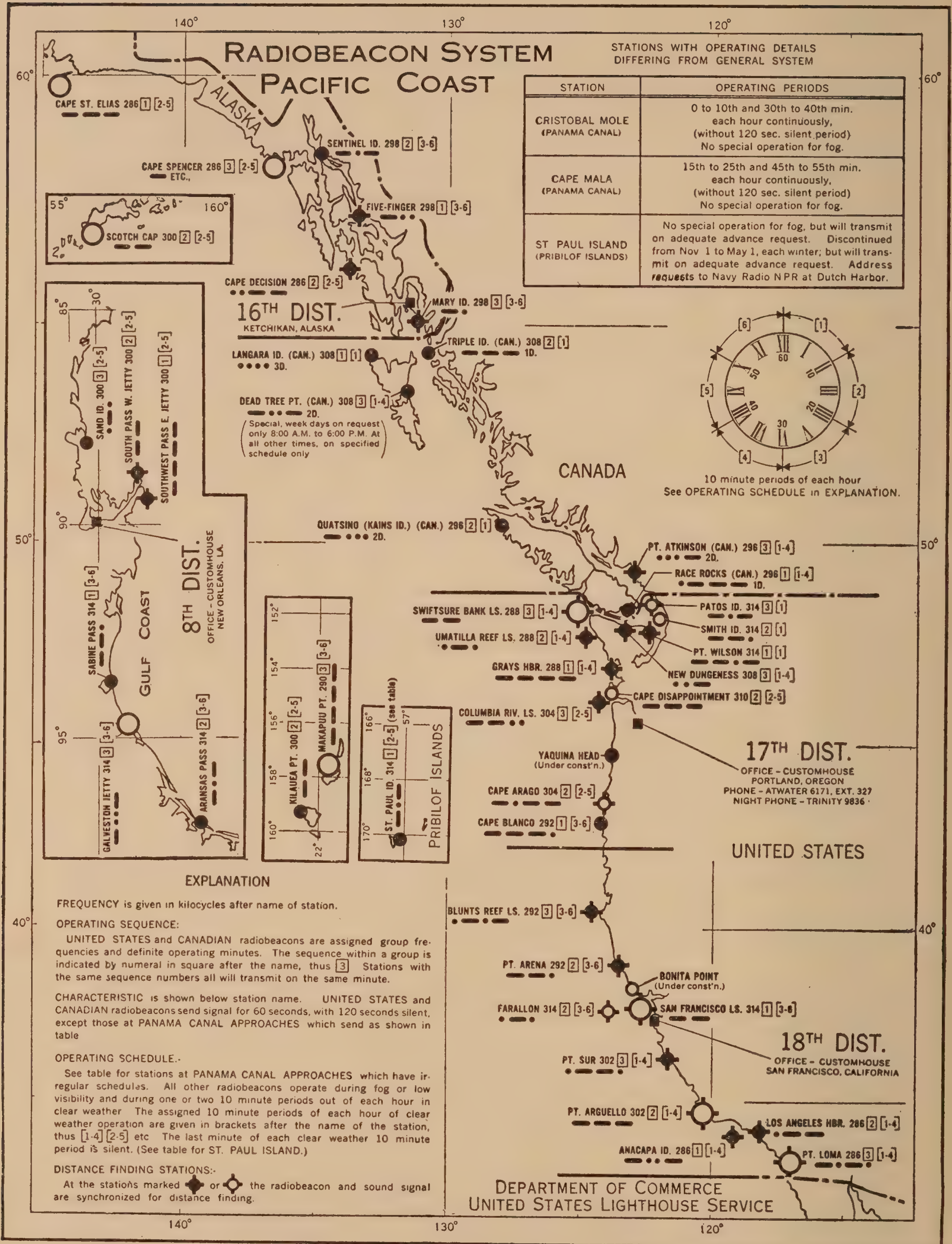
Answer. See Figure 58.

5.154. *Question.* **Draw a simple schematic diagram of an oscillating arc circuit, indicating the circuit elements necessary to identify this form of oscillatory circuit.**

Answer. See Figure 60.

5.155. *Question.* **Why is a push-pull audio-frequency amplifier preferable to a single-tube stage?**

Answer. The second and other even harmonics are cancelled in the output which minimizes distortion in the amplifier; greater power output; saturation of output


RADIOBEACON SYSTEM
PACIFIC COAST
140°
130°
120°
60°
50°
40°
ALASKA
CAPE ST. ELIAS 286 [1] [2-5]
CAPE SPENCER 286 [3] [2-5] ETC.,
SENTINEL ID. 298 [2] [3-6]
FIVE-FINGER 298 [1] [3-6]
SCOTCH CAP 300 [2] [2-5]
55°
160°
CAPE DECISION 286 [2] [2-5]
MARY ID. 298 [3] [3-6]
16TH DIST.
KETCHIKAN, ALASKA
TRIPLE ID. (CAN.) 308 [2] [1] 1D.
LANGARA ID. (CAN.) 308 [1] [1] 3D.
DEAD TREE PT. (CAN.) 308 [3] [1-4] 2D.
Special, week days on request only 8:00 A.M. to 6:00 P.M. At all other times, on specified schedule only
CANADA
QUATSINO (KAINS ID.) (CAN.) 296 [2] [1] 2D.
PT. ATKINSON (CAN.) 296 [3] [1-4] 2D.
RACE ROCKS (CAN.) 296 [1] [1-4] 1D.
SWIFTSURE BANK LS. 288 [3] [1-4]
PATOS ID. 314 [3] [1]
SMITH ID. 314 [2] [1]
UMATILLA REEF LS. 288 [2] [1-4]
PT. WILSON 314 [1] [1]
GRAYS HBR. 288 [1] [1-4]
NEW DUNGENESS 308 [3] [1-4]
CAPE DISAPPOINTMENT 310 [2] [2-5]
COLUMBIA RIV. LS. 304 [3] [2-5]
17TH DIST.
OFFICE - CUSTOMHOUSE
PORTLAND, OREGON
PHONE - ATWATER 6171, EXT. 327
NIGHT PHONE - TRINITY 9836
YAQUINA HEAD (Under const'n.)
CAPE ARAGO 304 [2] [2-5]
CAPE BLANCO 292 [1] [3-6]
UNITED STATES
BLUNTS REEF LS. 292 [3] [3-6]
PT. ARENA 292 [2] [3-6]
BONITA POINT (Under const'n.)
FARALLON 314 [2] [3-6]
SAN FRANCISCO LS. 314 [1] [3-6]
18TH DIST.
OFFICE - CUSTOMHOUSE
SAN FRANCISCO, CALIFORNIA
PT. SUR 302 [3] [1-4]
PT. ARGUELLO 302 [2] [1-4]
LOS ANGELES HBR. 286 [2] [1-4]
ANACAPA ID. 286 [1] [1-4]
PT. LOMA 286 [3] [1-4]
[6]
[1]
[2]
[3]
[4]
[5]
60
50
40
30
20
10
10 minute periods of each hour
See OPERATING SCHEDULE in EXPLANATION.
85°
30°
90°
95°
SAND ID. 300 [3] [2-5]
SOUTH PASS W. JETTY 300 [2] [2-5]
SOUTHWEST PASS E. JETTY 300 [1] [2-5]
8TH DIST.
OFFICE - CUSTOMHOUSE
NEW ORLEANS, LA.
SABINE PASS 314 [1] [3-6]
GULF COAST
GALVESTON JETTY 314 [3] [3-6]
ARANSAS PASS 314 [2] [3-6]
152°
154°
156°
158°
160°
22°
KILAUEA PT. 300 [2] [2-5]
MAKAPUU PT. 290 [3] [3-6]
166°
168°
170°
57°
ST. PAUL ID. 314 [1] [2-5] (see table)
PRIBILOF ISLANDS
DEPARTMENT OF COMMERCE
UNITED STATES LIGHTHOUSE SERVICE

STATIONS WITH OPERATING DETAILS DIFFERING FROM GENERAL SYSTEM

STATION	OPERATING PERIODS
CRISTOBAL MOLE (PANAMA CANAL)	0 to 10th and 30th to 40th min. each hour continuously, (without 120 sec. silent period) No special operation for fog.
CAPE MALA (PANAMA CANAL)	15th to 25th and 45th to 55th min. each hour continuously, (without 120 sec. silent period) No special operation for fog.
ST PAUL ISLAND (PRIBILOF ISLANDS)	No special operation for fog, but will transmit on adequate advance request. Discontinued from Nov 1 to May 1, each winter; but will transmit on adequate advance request. Address requests to Navy Radio NPR at Dutch Harbor.

EXPLANATION

FREQUENCY is given in kilocycles after name of station.

OPERATING SEQUENCE:

UNITED STATES and CANADIAN radiobeacons are assigned group frequencies and definite operating minutes. The sequence within a group is indicated by numeral in square after the name, thus [3] Stations with the same sequence numbers all will transmit on the same minute.

CHARACTERISTIC is shown below station name. UNITED STATES and CANADIAN radiobeacons send signal for 60 seconds, with 120 seconds silent, except those at PANAMA CANAL APPROACHES which send as shown in table

OPERATING SCHEDULE.-

See table for stations at PANAMA CANAL APPROACHES which have irregular schedules. All other radiobeacons operate during fog or low visibility and during one or two 10 minute periods out of each hour in clear weather The assigned 10 minute periods of each hour of clear weather operation are given in brackets after the name of the station, thus [1-4] [2-5] etc The last minute of each clear weather 10 minute period is silent. (See table for ST. PAUL ISLAND.)

DISTANCE FINDING STATIONS:-

At the stations marked ◆ or ◇ the radiobeacon and sound signal are synchronized for distance finding.

Fig. 98. Radiobeacon system. (*Courtesy of U. S. Lighthouse Service.*)

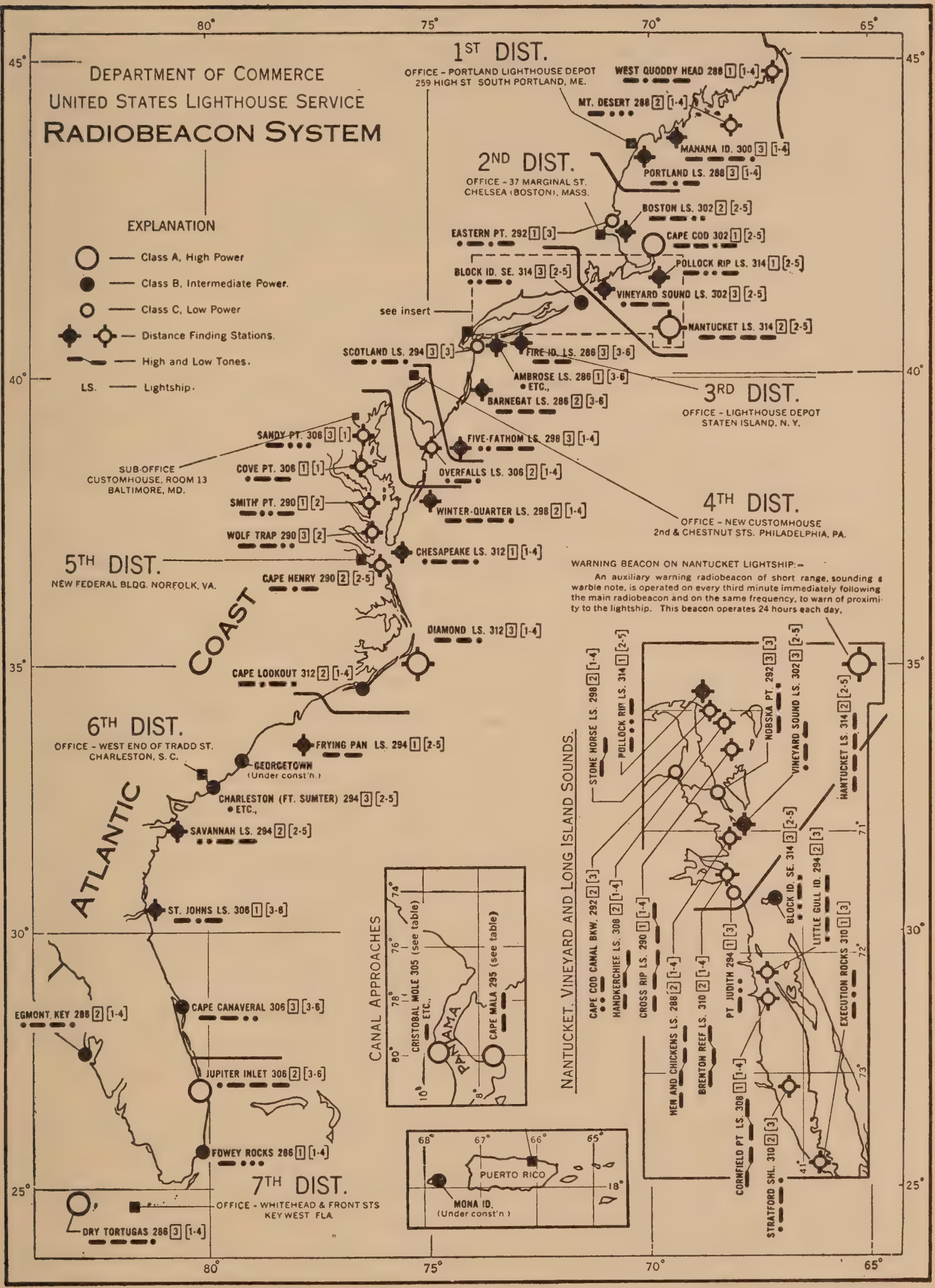

DEPARTMENT OF COMMERCE
UNITED STATES LIGHTHOUSE SERVICE
RADIOBEACON SYSTEM
EXPLANATION
Class A, High Power
Class B, Intermediate Power.
Class C, Low Power
Distance Finding Stations.
High and Low Tones.
LS. Lightship.
1ST DIST.
OFFICE - PORTLAND LIGHTHOUSE DEPOT 259 HIGH ST SOUTH PORTLAND, ME.
WEST QUODDY HEAD 288 [1] [1-4]
MT. DESERT 288 [2] [1-4]
MANANA ID. 300 [3] [1-4]
PORTLAND LS. 288 [3] [1-4]
2ND DIST.
OFFICE - 37 MARGINAL ST. CHELSEA (BOSTON), MASS.
BOSTON LS. 302 [2] [2-5]
EASTERN PT. 292 [1] [3]
CAPE COD 302 [1] [2-5]
BLOCK ID. SE. 314 [3] [2-5]
POLLOCK RIP LS. 314 [1] [2-5]
VINEYARD SOUND LS. 302 [3] [2-5]
NANTUCKET LS. 314 [2] [2-5]
see insert
SCOTLAND LS. 294 [3] [3]
FIRE ID. LS. 286 [3] [3-6]
AMBROSE LS. 286 [1] [3-6] ETC.,
BARNEGAT LS. 286 [2] [3-6]
3RD DIST.
OFFICE - LIGHTHOUSE DEPOT STATEN ISLAND, N. Y.
SANDY PT. 306 [3] [1]
FIVE-FATHOM LS. 298 [3] [1-4]
SUB-OFFICE CUSTOMHOUSE, ROOM 13 BALTIMORE, MD.
COVE PT. 306 [1] [1]
OVERFALLS LS. 306 [2] [1-4]
SMITH PT. 290 [1] [2]
WINTER-QUARTER LS. 298 [2] [1-4]
4TH DIST.
OFFICE - NEW CUSTOMHOUSE 2nd & CHESTNUT STS. PHILADELPHIA, PA.
WOLF TRAP 290 [3] [2]
CHESAPEAKE LS. 312 [1] [1-4]
5TH DIST.
NEW FEDERAL BLDG. NORFOLK, VA.
CAPE HENRY 290 [2] [2-5]
WARNING BEACON ON NANTUCKET LIGHTSHIP:- An auxiliary warning radiobeacon of short range, sounding a warble note, is operated on every third minute immediately following the main radiobeacon and on the same frequency, to warn of proximity to the lightship. This beacon operates 24 hours each day.
COAST
DIAMOND LS. 312 [3] [1-4]
CAPE LOOKOUT 312 [2] [1-4]
6TH DIST.
OFFICE - WEST END OF TRADD ST. CHARLESTON, S. C.
FRYING PAN LS. 294 [1] [2-5]
GEORGETOWN (Under const'n.)
CHARLESTON (FT. SUMTER) 294 [3] [2-5] ETC.,
SAVANNAH LS. 294 [2] [2-5]
ATLANTIC
ST. JOHNS LS. 306 [1] [3-6]
EGMONT KEY 286 [2] [1-4]
CAPE CANAVERAL 306 [3] [3-6]
JUPITER INLET 306 [2] [3-6]
FOWEY ROCKS 286 [1] [1-4]
7TH DIST.
OFFICE - WHITEHEAD & FRONT STS KEY WEST FLA.
DRY TORTUGAS 286 [3] [1-4]
CANAL APPROACHES
CRISTOBAL MOLE 305 (see table) ETC.,
CAPE MALA 295 (see table)
PANAMA
PUERTO RICO
MONA ID. (Under const'n.)
NANTUCKET, VINEYARD AND LONG ISLAND SOUNDS.
STONE HORSE LS. 298 [2] [1-4]
POLLOCK RIP LS. 314 [1] [2-5]
NOBSKA PT. 292 [3] [3]
VINEYARD SOUND LS. 302 [3] [2-5]
NANTUCKET LS. 314 [2] [2-5]
CAPE COD CANAL BKW. 292 [2] [3]
HANDKERCHIEF LS. 308 [2] [1-4]
CROSS RIP LS. 290 [1] [1-4]
HEN AND CHICKENS LS. 288 [2] [1-4]
BRENTON REEF LS. 310 [2] [1-4]
PT. JUDITH 294 [1] [3]
BLOCK ID. SE. 314 [3] [2-5]
LITTLE GULL ID. 294 [2] [3]
EXECUTION ROCKS 310 [1] [3]
CORNFIELD PT LS. 308 [1] [1-4]
STRATFORD SHL. 310 [2] [3]
45° 40° 35° 30° 25°
80° 75° 70° 65°

Fig. 99. Radiobeacon system. (*Courtesy of U. S. Lighthouse Service.*)

transformer core is minimized; less filtering required for a given permissible hum level.

5.156. ***Question.*** **Name several applications for vacuum tubes operating as class A audio amplifiers.**

Answer. Several applications of a class A audio amplifier are as follows:

(1) Preamplifiers for microphone use.
(2) Modulators.
(3) Indicating instruments using linear amplifiers.
(4) Speech input equipment and line amplifiers.
(5) Facsimile equipment.
(6) Phonograph pick-up amplifier.
(7) Receiver applications employing a-f voltage amplifiers.

5.157. ***Question.*** **What is the chief advantage of class A audio operation as compared with other classes of audio-frequency amplifiers?**

Answer. The main advantage of class A operation of an audio amplifier is low distortion because its output is essentially linear.

5.158. ***Question.*** **Why is the correct grid bias important in an audio-frequency amplifier?**

Answer. The correct grid bias is important because it locates the working point on the grid-voltage plate-current characteristic to give linear output wave form and thus minimizes distortion.

5.159. ***Question.*** **How may even harmonic energy be reduced in the output of an audio-frequency amplifier?**

Answer. Operating the stage push-pull effectively cancels the even harmonics.

5.160. ***Question.*** **Why are class A audio amplifiers not as critical, in so far as grid drive requirements are concerned, as class B audio amplifiers?**

Answer. Because the *bias* setting for a class A amplifier is not as critical as for class B. The bias for class A is adjusted "somewhere" on the linear curve and for class B it is as "projected" cutoff, that is, close to cutoff.

5.161. ***Question.*** **Name at least two uses of a class C radio-frequency amplifier in modern telegraph and telephone transmitters.**

Answer. Two uses of a class C amplifier are as a power amplifier in the final stage and in frequency multiplier stages. A class C amplifier is capable of large power output with high plate circuit efficiency and therefore finds wide application as a final amplifier. Since a class C amplifier generates a relatively high percentage of harmonics this class of operation is especially suited for use in doubler and tripler stages. Another common application of class C is in a modulated r-f amplifier stage.

5.162. ***Question.*** **Name several causes of excessive plate current in a radio-frequency amplifier.**

Answer. Excessive plate current may be caused by any of the following:

(1) Defective tube; soft tube.
(2) Insufficient grid bias.
(3) Excessive plate voltage.
(4) Excessive excitation voltage.
(5) Detuned plate tank circuit.

(6) Improper neutralization.
(7) Parasitic oscillations.

5.163. ***Question.*** **What is the chief advantage of a class B radio-frequency amplifier, and for what is this type of amplifier commonly employed?**

Answer. A class B radio-frequency amplifier is essentially a linear amplifier. A common application of a class B r-f amplifier is as a linear r-f power amplifier following a class C modulated stage.

5.164. ***Question.*** **What class of amplifier should follow a modulated radio-frequency amplifier?**

Answer. The stage after the modulated r-f stage should be operated class B in order to avoid the introduction of distortion. (See answer to Question 5.58.)

5.165. ***Question.*** **Define a "class C amplifier."**

Answer. A class C amplifier is one in which the plate current flows for appreciably less than 180° of the grid excitation cycle.

5.166. ***Question.*** **Why are bypass condensers used across the cathode bias resistors of radio-frequency amplifiers?**

Answer. Bypass condensers are used across cathode bias resistors of r-f amplifiers to prevent current inverse feedback and consequent loss in gain.

5.167. ***Question.*** **What is the main advantage of a tuned audio-frequency amplifier in a receiver used for the reception of radiotelegraph signals?**

Answer. Increased selectivity is gained by providing a tuned audio-frequency amplifier which may be adjusted to the beat frequency of the desired signal. Thus beat frequencies close to the frequency to which the receiver is tuned are discriminated against, which is an advantage in C-W reception. These beat frequencies result from interfering signals.

5.168. ***Question.*** **What is the purpose of decoupling networks in the plate circuits of a multistage audio amplifier?**

Answer. The purpose of decoupling networks is to prevent regenerative coupling and oscillation between the stages due to the common impedance of the plate power supply. The frequency of such oscillation, when permitted, is usually very low and is called "motor-boating."

5.169. ***Question.*** **What is a "buffer" amplifier and what are its applications?**

Answer. A "buffer" amplifier is an r-f amplifier which is operated in a manner to provide adequate plate isolation between a previous stage, or oscillator, and subsequent r-f stages for minimizing circuit reactions that cause frequency instability. One or more buffer stages usually follow the oscillator in a radiotelephone transmitter. By employing loose coupling and by operating the buffer stage not primarily for gain it effectively prevents the oscillator plate circuit load from being affected by modulation or by plate load changes in the power amplifier stages.

5.170. ***Question.*** **For what purpose is a "frequency doubler" stage used in a transmitter?**

Answer. The purpose of a frequency doubler stage is to provide a frequency in the output which is twice the frequency of the r-f exciting voltage. The practical purpose is to allow the use of a low-frequency crystal oscillator with its advantages over a high-frequency oscillator. The desired operating frequency selected will be some even multiple of the oscillator's fundamental frequency.

5.171. *Question.* Describe the operation of a "frequency doubler" stage.

Answer. The grid bias of a frequency doubler is adjusted beyond cutoff as in class C service and consequently its output contains a high percentage of harmonics; the plate tank circuit is tuned to twice the frequency, or second harmonic, of the exciting voltage applied to the grid. In operation the plate tank receives one pulse of plate current over a small portion of the least negative half of the excitation cycle and the tank continues to oscillate and produce two cycles until the next plate current pulse. Therefore each cycle of grid excitation produces two cycles of current circulating in the plate tank. This harmonic is available for further doubling in subsequent stages.

5.172. *Question.* Why is neutralization often necessary in a radio-frequency amplifier?

Answer. Neutralization prevents self-oscillation in a radio-frequency amplifier. Most r-f amplifiers will oscillate at their own frequency when the plate and grid circuits are tuned to resonance, but when properly neutralized the amplifier will operate only on the frequency at which it is being driven.

5.173. *Question.* What is the purpose of shielding between radio-frequency amplifier stages?

Answer. Shielding of the r-f stages prevents interaction or feedback between the various circuit components that might cause instability or oscillation in the stages. Also, adequate shielding will often eliminate neutralizing difficulties.

5.174. *Question.* Describe how a radio-frequency amplifier stage may be neutralized.

Answer. See answer to Question 5.98.

5.175. *Question.* In neutralizing a radio-frequency amplifier stage of a transmitter, using a thermocouple galvanometer as an indicator, what precautions must be observed?

Answer. A thermocouple galvanometer is a very sensitive instrument which could be easily burned out by coupling the pick-up coil of the indicator too close to the plate tank coil. The coupling should be as loose as practicable to give a reliable indication. All types of r-f indicators should be removed before applying plate voltage after neutralization is completed and the stage is ready to be tuned.

5.176. *Question.* Draw a complete schematic diagram of a system of inductive coupling between the output of a radio-frequency amplifier and an antenna system.

Answer. See Figure 84.

5.177. *Question.* Draw a simple schematic diagram showing a method of "link" coupling between two radio-frequency amplifier stages.

Answer. See Figure 54.

5.178. *Question.* Draw a simple schematic diagram showing a method of "direct" coupling between two stages of an audio-frequency amplifier.

Answer. See Figure 63.

5.179. *Question.* Draw a simple schematic diagram showing a method of "impedance" coupling between two stages of a radio-frequency amplifier.

Answer. See Figure 62.

5.180. ***Question.*** **Draw a simple schematic diagram showing a method of inductive or transformer coupling between two stages of a radio-frequency amplifier.**

Answer. See Figure 62.

5.181. ***Question.*** **Discuss the characteristics of a dynatron oscillator.**

Answer. The characteristics of a dynatron oscillator are excellent frequency stability, low output, and low efficiency. The dynatron oscillator is useful as a reference and for calibration purposes in instruments such as a heterodyne frequency meter. Its use in general is restricted because of the low output.

5.182. ***Question.*** **What type of oscillator depends upon secondary emission from the anode for its operation?**

Answer. Dynatron oscillator. (See answer to Question 5.146.)

5.183. ***Question.*** **What is the primary reason for the suppression of radio-frequency harmonics in the output of a transmitter?**

Answer. The primary reason for harmonic suppression is to prevent interference to other radio services whose transmissions bear a harmonic relation to the transmitter's frequency. In addition, harmonic output represents wasted power.

5.184. ***Question.*** **In a radiotelegraph transmitter employing a d-c generator as a source of plate voltage, an a-c generator as filament supply and grid bias keying, if it is noted that when the key contacts are open the emission continues, what could be the trouble?**

Answer. The trouble might be caused by any of the following, which indicate that the high bias, or blocking bias, is not being applied to the grid: Shorted high bias resistor; grid return shorted to ground; shorted key circuit or short in key click filter elements; defective relay key or the relay key contacts controlling the high blocking bias may be stuck.

5.185. ***Question.*** **What is the purpose of an electrostatic shield?**

Answer. The purpose of an electrostatic shield is to prevent the transfer of energy from one circuit to another by means of capacity coupling. A Faraday screen is one example of an electrostatic shield. Another is the electrostatic shielding between primary and secondary of a power transformer to prevent r-f disturbances in a mercury-vapor type rectifier from being transmitted to the line.

5.186. ***Question.*** **What is the advantage of link coupling between radio-frequency amplifier stages?**

Answer. Link coupling permits inductive coupling with its advantages to be used between stages which are separated a considerable distance. Link coupling forms a low-impedance transmission line consisting of a pair of leads with a coupling coil of a few turns at each end. The link coils should be coupled to the respective tank coils of the two stages at a point of zero or low radio-frequency potential. See answer to Question 2.177.

5.187. ***Question.*** **Draw a simple schematic diagram showing how a radiotelegraph transmitter may be keyed by the "grid blocking" method.**

Answer. See Figure 100.

5.188. ***Question.*** **Discuss methods of keying a high power radiotelegraph transmitter.**

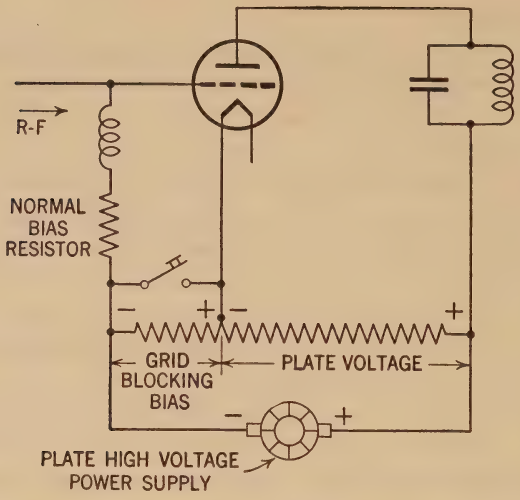


FIG. 100. Keying is accomplished by using blocking bias on the grid.

Answer. The most satisfactory means of keying a high power radiotelegraph transmitter is by applying a high negative bias voltage which will block the plate current and stop oscillation. The high bias is easily obtained by connecting a voltage divider across the plate voltage supply and connecting the grid return lead to the negative end and the cathode to a point on the divider that gives the required blocking voltage. The key contacts are connected across this resistor section so that with the key closed for sending, the high bias is removed to permit oscillation and with the key up, the blocking bias is applied to drop the plate current to zero, which stops oscillation.

5.189. ***Question.*** **What is meant by "grid block keying"?**

Answer. Grid block keying means that the key contacts control the removal and applying of a high negative bias voltage to the grid, which allows the plate current to flow with the key down and stops it with the key up.

5.190. ***Question.*** **Draw a simple schematic diagram of a "key click filter" suitable for use when a vacuum tube transmitter is keyed in the negative high-voltage circuit.**

Answer. See Figure 101.

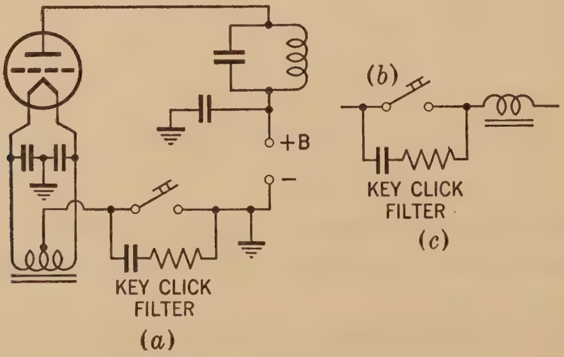


FIG. 101. Example of a key click filter.

5.191. ***Question.*** **Draw a simple schematic diagram of a system of keying in the primary of the transformer supplying high voltage to a vacuum tube transmitter. Indicate any values of inductance, resistance, and capacitance which may be deemed necessary to fully understand the correct operation of this type of keying**

Answer. See Figure 102.

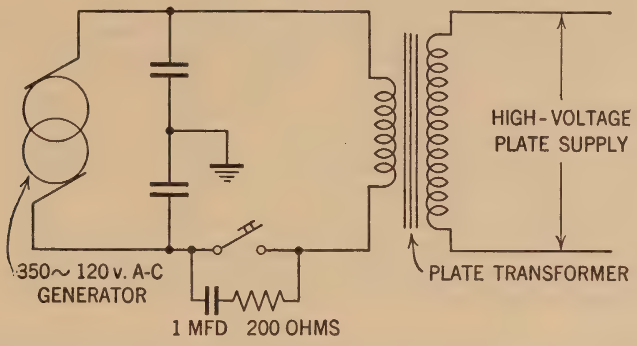


FIG. 102. Example of a tone generator connected in the primary of a power transformer.

5.192. ***Question.*** **A transmitter is operating on 5,000 kilocycles, using a 1,000-kilocycle crystal with a temperature coefficient of −4 cycles per megacycle per degree Centigrade. If the crystal temperature increases 6° Centigrade, what is the change in the output frequency of the transmitter?**

Answer. The change in the output frequency is 120 cycles lower than 5,000 kilocycles, or the new operating frequency is 4,999.88 kilocycles.

Calculation: The crystal frequency is 1,000 kilocycles, or 1 megacycle, and this frequency decreases (negative temperature coefficient) 4 cycles for each degree of temperature change, or $4 \times 6 = -24$ cycles change in a million. But the operating frequency is 5 megacycles, and therefore this frequency is lowered by 5×24, or −120 cycles.

5.193. ***Question.*** **What may cause a positive carrier shift in a linear radio-frequency amplifier output?**

Answer. Positive carrier shift means that the amplitudes of the positive halves of the modulated r-f carrier are greater than the negative halves and consequently the carrier power shifts upward. The following might cause this condition:

Insufficient r-f excitation.
Excessive grid bias.
Poor regulation of bias supply.
Detuned circuits.
Overmodulation.
Modulator stage; excessive bias or insufficient excitation.

5.194. ***Question.*** **What is the second harmonic of 380 meters?**

Answer. 190 meters.

5.195. ***Question.*** **What is the effect of excessive coupling between the output circuit of a simple oscillator and an antenna?**

Answer. Excessive coupling results in a split tuning effect, which may cause the operating frequency to jump suddenly to some other frequency. A receiver tuned to the operating frequency of the transmitter would lose the signal entirely from split tuning. Furthermore, off-frequency emissions are in violation of the radio laws.

Discussion. Split tuning may be avoided with proper adjustment by loosening the coupling gradually and for each coupling change make the following check: First detune the antenna. Retune the antenna to resonance as indicated by maximum antenna current and carefully note the position of the tuning dial on the scale. Then continue adjusting the dial in the same direction, which detunes the antenna. Retune the antenna again and at resonance note the position of the tuning dial on the scale. If these dial positions do not coincide then loosen the coupling and make another trial and continue with this procedure until the same dial setting is found at resonance each time the antenna is tuned back and forth through resonance. Close coupling results in a response curve having two pronounced peaks or humps, so that when the foregoing test is made the antenna may show two different resonant points on the dial. These points come closer together as the coupling is loosened, and when they coincide it indicates a flat-topped response curve or one having only one peak. This curve could be peaked further for sharper tuning by loosening the coupling still more, but this change would result in unnecessarily lowering the power.

5.196. ***Question.*** **A station has an assigned frequency of 8,000 kilocycles and a frequency tolerance of plus or minus 0.04 per cent The oscillator operates at one-eighth of the output frequency What is the maximum permitted deviation of the oscillator frequency, in cycles, which will not exceed the tolerance?**

Answer. 400 cycles, plus or minus the oscillator frequency.

Computation: The tolerance in cycles for the assigned frequency is 8,000 kc × 0.0004 = 3.2 kc, or 3,200 cycles. Since the oscillator operates at ⅛ of the assigned frequency then the oscillator's tolerance is ⅛ of 3,200 cycles, or 400 cycles. These relations may be given as follows:

$$3.2 : 8{,}000 :: x : 1{,}000$$

or

$$8{,}000x = 3{,}200$$

and

$$x = \pm 0.4 \text{ kilocycles, or } \pm 400 \text{ cycles}$$

5.197. ***Question.*** **What is meant by "self-wiping" contacts as used in connection with relays?**

Answer. Contacts which slide or rub together on closing or opening are called "self-wiping" contacts. The rubbing action keeps the contact surfaces clean and in good condition, which would not be the case if the contacts merely butt together.

5.198. ***Question.*** **Why are permanent magnets used in head telephones? In d-c meters?**

Answer. Permanent magnets are used in headphones to place the diaphragms under a tension so that small signal currents in the windings will produce relatively large amplitude changes which increase the sensitivity; the diaphragms being held under stress by the pull of the magnets results in a better frequency response. Permanent magnets are used in d-c meters to provide a pole piece of constant flux density which will cause motion of the coil carrying the pointer, the action being similar in principle to the rotation of a motor armature in a field of constant flux density.

5.199. ***Question.*** **What devices may be used as indicators of radio-frequency energy?**

Answer. Thermocouple ammeter; hot-wire ammeter; neon bulb; flashlight bulb used with a loop of wire; vacuum-tube voltmeter; cathode-ray oscilloscope.

5.200. ***Question.*** **What is the correct value of negative grid bias, for operation as a class B amplifier, for a vacuum tube of the following characteristics: Plate voltage 1,000 volts, plate current 127 milliamperes, filament voltage 4 volts, filament current 5.4 amperes, mutual conductance 8,000 micromhos, and amplification factor 25?**

Answer. —40 volts, approximately.

Computation: The bias voltage may be determined approximately from the following formula:

$$-E_c = \frac{E_b}{\mu} = \frac{1{,}000}{25} = -40 \text{ volts}$$

Note. In practice the grid bias voltage is given with respect to the midpoint of the filament when a.c. is used A deduction is made for operation with d.c. The problem does not state the type of filament supply.

5.201. ***Question.*** **Is an oscillator ever neutralized? Discuss.**

Answer. No. The purpose of an oscillator is to generate oscillations, and neutralizing would prevent oscillation.

5.202. ***Question.*** **What is the definition of type B emission?**

Answer. Type B emission is classified under damped waves and defined as follows: Waves consisting of successive series of oscillations of which the amplitude, after having reached a maximum, decreases gradually, the wave trains being keyed according to a telegraph code.

5.203. ***Question.*** **Define type A0, A1, A2, A3, A4, and A5 emission.**

Answer. The emissions classified as continuous waves, or type A, are as follows:

Type A0.	Waves the successive oscillations of which are identical under fixed conditions.
Type A1.	Telegraphy on pure continuous waves. A continuous wave which is keyed according to a telegraph code.
Type A2.	Modulated telegraphy. A carrier wave modulated at one or more audible frequencies, the audible frequency or frequencies or their combination with the carrier wave being keyed according to a telegraph code.
Type A3.	Telephony. Waves resulting from the modulation of a carrier wave by frequencies corresponding to the voice, to music, or to other sounds.
Type A4.	Facsimile. Waves resulting from the modulation of a carrier wave by frequencies produced at the time of the scanning of a fixed image with a view to its reproduction in a permanent form.
Type A5.	Television. Waves resulting from the modulation of a carrier wave by frequencies produced at the time of the scanning of fixed or moving objects.

5.204. ***Question.*** **In the aerial mobile service, what is the maximum period of time that operation of 333 kilocycles is permitted?**

Answer. In no case, in the aeronautical mobile service, must working on 333 kilocycles (900 meters) exceed 5 minutes. (General Radio Regulations, Revision of Cairo, 1938. Article 17, § 8 [1-b].)

5.205. *Question.* Who may authorize tests or experiments by other than mobile stations?

Answer. The Federal Communications Commission through the inspector in charge of the proper field office. In accordance with F.C.C. Rule 2.47 station licensees are authorized to carry on such routine tests as may be required for the proper maintenance of the stations under the rules and regulations governing the class of station concerned, provided that the tests shall be so conducted as not to cause interference with the service of other stations.

5.206. *Question.* What is the maximum period of time during which test "V's" may be transmitted for purposes of adjusting a transmitter?

Answer. When it is necessary to make test signals, either for the adjustment of a transmitter before making a call or for the adjustment of a receiver, these signals must not continue for more than 10 seconds and must be composed of a series of VVV followed by the call sign of the station emitting the test signals. (General Radio Regulations, Revision of Cairo, 1938. Article 17, § 9.)

5.207. *Question.* In all cases other than those in which the transmitter output must be maintained at a fixed value, what amount of power should be employed for routine communications?

Answer. The minimum amount of power necessary to ensure reliable communication should be used at all times.

5.208. *Question.* What is the radiotelegraph urgent signal?

Answer. In radiotelegraphy, the urgency signal consists of three repetitions of the group XXX, sent with the letters of each group and the successive groups clearly separated from each other; it is sent before the call. (General Radio Regulations, Revision of Cairo, 1938. Article 24, § 22 [1].)

5.209. *Question.* What is the urgent signal for radiotelegraph use in the aeronautical service?

Answer. In the aeronautical service, the urgency signal PAN is used both in radiotelegraphy and radiotelephony to indicate that the aircraft sending it is in difficulty and obliged to land but that it has no need of immediate assistance. This signal must, so far as practicable, be followed by a message giving further information.

5.210. *Question.* What is the meaning of the spoken expression "MAYDAY"?

Answer. The spoken expression "MAYDAY" is a distress signal and means that the ship, aircraft or other vehicle sending the signal is threatened by grave and imminent danger and requests immediate assistance.

5.211. *Question.* In radiotelegraphy, what is the safety signal?

Answer. In radiotelegraphy, the safety signal consists of three repetitions of the group TTT, sent with the letters of each group and the successive groups clearly separated from each other. This signal is followed by the word DE and by the call sign of the station which emits it, sent three times. It indicates that the station is about to transmit a message concerning the safety of navigation or giving important meteorological warnings.

5.212. *Question.* What is the maximum transmission speed to be used in connection with distress, emergency, or safety transmissions?

Answer. The speed of telegraph transmission in cases of distress, urgency, or safety must not normally exceed 16 words a minute.

5.213. *Question.* What is the general call "to all stations"?

Answer. Two types of call signal "to all stations" are recognized:

1. The call CQ followed by the letter K (general call to all stations in the mobile service with request for reply).

2. The call CQ not followed by the letter K (general call to all stations without request for reply).

5.214. *Question.* What is the radiotelephone urgent signal?

Answer. In radiotelephony, the urgency signal consists of three repetitions of the expression PAN (corresponding to the French pronunciation of the word *panne*); it is sent before the call.

5.215. *Question.* What is the radiotelegraph distress signal?

Answer. In radiotelegraphy, the distress signal consists of the group •••———•••, transmitted as a single sign in which the dashes must be emphasized so as to be distinguished clearly from the dots.

5.216. *Question.* What classes of stations may be operated by the holder of a restricted radiotelegraph operator permit?

Answer. Any station while using type B, A0, A1, A2, A3, or A4 emission: Provided that, in the case of equipment designed for and using type A3 or A4 emission —

(1) Such operator is prohibited from making adjustments that may result in improper transmitter operation.

(2) The equipment is so designed that none of the operations necessary to be performed during the course of normal rendition of service may cause off-frequency operation or result in any unauthorized radiation.

(3) Any needed adjustments of the transmitter which may affect proper operation of the station are regularly made by or in the presence of an operator holding a first- or second-class license, either telephone or telegraph, who shall be responsible for the proper operation of the equipment.

Exceptions.

(1) The permit is not valid for the operation of any of the various classes of broadcast stations other than a relay broadcast station.

(2) The permit is not valid for the operation of a ship station licensed to use type A3 emission for communication with coastal telephone stations.

(3) The license is not valid for the operation of a radiotelegraph station on board a vessel required by treaty or statute to be equipped with a radio installation.

(4) The license is not valid for the operation of any ship telegraph, coastal telegraph, or marine-relay station open to public correspondence.

5.217. *Question.* For what period of time must a station log which contains entries incident to a disaster be retained?

Answer. Logs containing communications incident to a disaster or including communications incident to or involved in an investigation by the Commission and concerning which the licensee has been notified shall be retained by the licensee until specifically authorized in writing by the Commission to destroy them.

5.218. *Question.* What is the meaning of "frequency tolerance"?

Answer. "Frequency tolerance" is the allowed deviation in frequency, generally expressed in per cent of the frequency of emission, from the assigned frequency as specified in the regulations governing the class of station concerned.

5.219. *Question.* Under what circumstances may a station be operated by an unlicensed person?

Answer. The actual operation of all transmitting apparatus in any licensed radio station shall be carried on only by a person holding an operator's license in such station. However, it is provided that the Commission if it shall find that the public interest, convenience, or necessity will be served thereby may waive or modify the foregoing provisions for the operation of any station except (1) stations for which licensed operators are required by international agreement, (2) stations for which licensed operators are required for safety purposes, (3) stations engaged in broadcasting, and (4) stations operated as common carriers on frequencies below 30,000 kilocycles. Further provisions give the Commission power to make special regulations governing the granting of licenses for the use of automatic radio devices and for the operation of such devices. (Communications Act of 1934, as amended, Sec. 318.)

5.220. *Question.* If an operator is employed at more than one station, how may he comply with the rule requiring the posting of operator licenses?

Answer. The holder of a radiotelegraph or radiotelephone first- or second-class license who is employed as a service and maintenance operator at stations operated by holders of Restricted Operator Permits shall post at such stations his operator license or a verified statement from the Commission in lieu thereof.

5.221. *Question.* If, upon being called by another station, a called station is unable to proceed with the acceptance of traffic, what should the operator of the called station do?

Answer. If the station called is prevented from receiving, it shall reply to the call as indicated in the General Radio Regulations, but it shall replace the letter K by the signal ·—··· (wait), followed by a number indicating in minutes the probable duration of the wait. If this probable duration exceeds 10 minutes (5 minutes in the aeronautical mobile service), a reason must be given therefor.

5.222. *Question.* What is the definition of a "station open to public service"?

Answer. A station open to public service is a station which handles public correspondence, paid or toll messages, or provides radiotelephone facilities for the general public at prescribed rates.

5.223. *Question.* Under what circumstances may the Commission authorize the control of a radiotelegraph transmitter with the operator at a point other than the location of the transmitter proper?

Answer. An operator or operators may be on duty at the control station in lieu of the place where the transmitting apparatus is located subject to the following conditions:

1. The transmitter shall be capable of operation and shall be operated in accordance with the terms of the station license.
2. The transmitter shall be so located and housed that it is not accessible to other than duly authorized persons.
3. The emissions of the transmitter shall be continuously monitored at the control point by a licensed operator of the grade specified for the class of station involved.
4. Proper apparatus and methods shall be provided so that the transmitter can quickly and without delay be placed in an inoperative condition in the event there is a deviation from the terms of the station license.
5. The radiation of the transmitter shall be suspended immediately when there is a deviation from the terms of the station license.

5.224. *Question.* **How is an experimental station restricted with regard to message traffic?**

Answer. Experimental stations shall not be used to conduct general message traffic of any kind, to demonstrate equipment for prospective sales purposes, to transmit programs for direct entertainment, to transmit the programs of any other station, except in conjunction with experimental programs, or to render any commercial communication service or communications involving advertising, either directly or indirectly, subject to specific limitations and restrictions which will be prescribed in individual cases by the Commission. This authority will be granted only for special reasons to obtain information or data which give promise of being of benefit to the radio art.

5.225. *Question.* **Describe the procedure of a radiotelegraph transmission in which one station calls another.**

Answer. The call is made as follows: Call sign of the station called, not more than three times; the word DE; call sign of the station calling, not more than three times.

5.226. *Question.* **What is the total reactance when two capacitances of equal value are connected in series?**

Answer. The total reactance is equal to the sum of the two reactances.

5.227. *Question.* **What are the effects of overexcitation of a class B amplifier grid circuit?**

Answer. The following effects result from overexcitation of a class B amplifier:

High plate dissipation; excessive plate current.
Plate circuit efficiency decreased.
Power output decreased.
Large distortion; increased harmonics; nonlinearity of operation.
Excessive grid current.

5.228. *Question.* **Name several devices that could be used to indicate oscillation in a crystal oscillator.**

Answer. Oscillation in a crystal oscillator could be indicated by any of the following:

Plate d-c milliammeter.
Grid d-c milliammeter.

Neon bulb.
Thermogalvanometer in plate tank circuit.
Absorption type r-f indicator.

Examples of r-f indicators in which a pick-up coil is coupled to the oscillator plate tank are: vacuum-tube voltmeter, cathode-ray oscilloscope, frequency meter, thermogalvanometer in series with a one- or two-turn loop.

5.229. ***Question.*** **What is the effect of loose laminations in a filter choke?**

Answer. Loose laminations may produce a hum or chattering in a severe case.

5.230. ***Question.*** **What is a desirable feature of an electrolytic condenser as compared to other types?**

Answer. Large capacitances are obtained from electrolytic condensers having relatively small physical dimensions which would not be possible in other types. The self-healing properties of a wet electrolytic condenser give this type an advantage over other condensers in which a breakdown of the dielectric would result in permanent damage.

5.231. ***Question.*** **Why is an additional plate-grid feedback condenser sometimes necessary in a crystal oscillator?**

Answer. A crystal oscillator circuit employing a tetrode or pentode tube and in which oscillation depends upon the feedback by means of the capacitance between plate and control grid usually requires this feedback to be supplied by a small adjustable condenser connected between these electrodes. The external feedback coupling is necessary owing to the effective screening between plate and control grid in a tetrode or pentode which gives such tubes a very low internal grid-plate capacitance. It is essential to keep the external coupling capacitance very small so that the feedback never becomes so large as to overload and possibly shatter the crystal.

5.232. ***Question.*** **Who may authorize tests or experiments by stations other than mobile stations?**

Answer. See Question 5.205.

ELEMENT 6

ADVANCED RADIOTELEGRAPHY

6.1. *Question.* What are the ratios between the average, effective, and peak values of a sinusoidal wave?

Answer. The following gives the various ratios:

Peak to effective = 1 : 0.707

Effective to peak = 1 : 1.141

Peak to average = 1 : 0.636

Average to peak = 1 : 1.57

Effective to average = 1 : 0.9

Average to effective = 1 : 1.11

6.2. *Question.* Define the following terms: hysteresis, permeability, eddy currents.

Answer. **Hysteresis.** Magnetic "hysteresis" is the property of a magnetic material by virtue of which the magnetic induction for a given magnetizing force depends upon the previous conditions of magnetization. (A.I.E.E. definition.)

In popular terms "hysteresis" in a magnetic material refers to the rearrangement of molecules which lags behind the magnetizing force, causing a heat loss owing to the molecular friction.

Note. The terms "hysteresis" and "hysteresis loss" are closely related, the latter being defined as follows: Magnetic hysteresis loss in a material for a specified cycle of magnetizing force is the energy converted into heat as a result of magnetic hysteresis when the magnetic induction is also cyclic. (A.I.E.E. definition.)

Permeability. "Permeability" is the specific conductivity of a substance for magnetic flux, the magnetic conductivity of air being used as a standard basic unit for comparison. Permeability from a practical viewpoint may be considered as the relative ease with which magnetic lines can be set up in a magnetic material in comparison with the same lines being set up in air.

Eddy currents. "Eddy currents" are those currents which are induced in a body of a conducting mass by a variation of magnetic flux.

Note. The variation of magnetic flux may be the result of a varying magnetic field or of a relative motion of the mass with respect to the magnetic field. (A.I.E.E. definition.) Eddy currents are also known as Foucault currents.

6.3. **Question.** **What is the total impedance of a series a-c circuit having an inductive reactance of 14 ohms, a resistance of 6 ohms, and a capacitive reactance of 6 ohms?**

Answer. The total or resultant impedance is 10 ohms.

Computation: Insert the given values in the impedance formula and solve as follows:

$$Z_{\text{total}} = \sqrt{(R_{\text{total}})^2 + (X_{\text{total}})^2}$$

$$R_{\text{total}} = 6 \text{ ohms}$$

$$X_{\text{total}} = 14 - 6 = 8 \text{ ohms (reactive)}$$

$$Z_{\text{total}} = \sqrt{6^2 + 8^2} = \sqrt{100} = 10 \text{ ohms}$$

6.4. **Question.** **What is the total impedance of a series a-c circuit having a resistance of 3 ohms, an inductive reactance of 7 ohms, and zero capacitive reactance?**

Answer. The total impedance is 7.62 ohms.

Computation: Apply the impedance formula as follows:

$$Z_{\text{total}} = \sqrt{(R_{\text{total}})^2 + X_{\text{total}})^2}$$

Since $R_{\text{total}} = 3 \text{ ohms}$

and $X_{\text{total}} = 7 - 0 = 7 \text{ ohms (reactive)}$

then $Z_{\text{total}} = \sqrt{3^2 + 7^2} = \sqrt{58} = 7.62 \text{ ohms}$

6.5. **Question.** **What changes in circuit constants will double the resonant frequency of a resonant circuit?**

Answer. This can be accomplished by (*a*) halving *both* L and C, or (*b*) by keeping L the same and making C one-fourth its previous value, or (*c*) by keeping C the same and making L one-fourth its previous value.

Discussion. Referring to the frequency formula below, it is seen that the product LC must be made ¼ its previous value to double the frequency.

$$f = \frac{1}{2\pi\sqrt{LC}}$$

6.6. **Question.** **How may the Q of a parallel resonant circuit be increased?**

Answer. The Q of a parallel resonant circuit must refer to the figures of merit of its components because at resonance the Q of the circuit taken as a whole is *zero*. Accordingly we should use a coil whose L/R is as high as possible and a condenser with as small a leakage as possible. Stated in another way, the Q value of both coil and condenser should be as high as possible and therefore low-loss parts should be used.

6.7. **Question.** **If a parallel circuit which is resonant at 1,000 kilocycles has its value of inductance halved and of capacitance doubled, what will be the resultant resonant frequency?**

Answer. The frequency remains unchanged and therefore is at its previous value of 1,000 kilocycles.

Proof: Stated generally: If L and C are varied such that $L \times C$ remains unchanged then the frequency remains unchanged. The following proof is given for this statement.

Let

$$f_1 = \frac{1}{2\pi\sqrt{L_1C_1}}, \quad \text{where } \left.\begin{matrix} L_1 \\ C_1 \\ f_1 \end{matrix}\right\} \text{are initial values.}$$

Now

$$f_2 = \frac{1}{2\pi\sqrt{L_2C_2}}, \quad \text{where } \left.\begin{matrix} L_2 \\ C_2 \\ f_2 \end{matrix}\right\} \text{are values after change.}$$

From the problem:

$$L_2 = \frac{L_1}{2} \quad \text{and} \quad C_2 = 2C_1$$

or

$$L_2C_2 = L_1C_1$$

Whence $$f_2 = \frac{1}{2\pi\sqrt{L_1C_1}} = f_1, \text{ or the frequency remains unchanged.}$$

6.8. *Question.* Assume a resistance of 8 ohms in parallel with a resistance of 6 ohms; in series with this combination is a resistance of 77 ohms. What is the total resistance of this combination?

Answer. The total resistance is 80.42 ohms.

Computation: Find the effective resistance of the parallel combination to which is added the series resistance of 77 ohms, as follows:

$$R_{\text{eff}} = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{8 \times 6}{8 + 6} = 3.42 \text{ ohms}$$

$$R_{\text{eff}} + R_3 = 3.42 + 77 = 80.42 \text{ ohms}$$

6.9. *Question.* Assume an inductance of 5 henrys in parallel with a capacitance of 1 microfarad. If there is no resistance in either leg of this circuit, what is the equivalent impedance of the parallel network at resonance?

Answer. The equivalent impedance at resonance is an infinite number of ohms. (See Question 5.33 for theory.)

6.10. *Question.* Why are iron cores of the type used in audio-frequency transformers not used in radio-frequency transformers?

Answer. If an iron core suitable for audio frequencies were used in a radio-frequency coil it would cause excessive eddy current losses and would greatly increase the radio-frequency resistance (decrease Q) of the coil. This would result in an unusual broadening of the tuning, which would destroy the selective qualities required of a radio-frequency circuit. A core of special grade powdered iron is required when used with r-f coils to provide good tuning properties and adjustment of band width.

6.11. *Question.* Why should the metallic case of a high-voltage transformer be "grounded"?

Answer. Grounding an exposed metallic part like a transformer case is a protection to personnel against possible high-voltage shock. A safety gap is usually provided across the secondary so that grounding the case permits disruptive high-voltage surges to dissipate directly to ground. By grounding the case and other nearby parts electrostatic fields cannot be set up between them. With the case grounded, a faulty ground in the transformer cannot build up voltages dangerous to connected equipment.

6.12. *Question.* What turns ratio should a transformer have which is to be used to match a source impedance of 500 ohms to a load of 10 ohms?

Answer. The primary to secondary turns ratio should be 7.1 to 1.

Computation: Insert the given values in the formula and solve, thus

$$\text{Turns ratio } \frac{N_p}{N_s} = \sqrt{\frac{Z_p}{Z_s}} = \sqrt{\frac{500}{10}} = \frac{7.1}{1}$$

6.13. *Question.* What would happen if a transformer designed for operation on 60 cycles were connected to a 120-cycle source of the same voltage?

Answer. The primary impedance would be greater at the higher frequency, thus lowering the primary exciting current, and the transformer would not deliver its rated power.

6.14. *Question.* What would happen if a transformer designed for operation on 500 cycles were connected to a 60-cycle source of the same voltage?

Answer. A very large current would be drawn by the primary owing to its low impedance at 60 cycles and the winding would overheat badly, which might cause it to burn out.

6.15. *Question.* What is the principal disadvantage of using a dynamotor rather than a motor-generator to furnish plate power to a small mobile transmitter?

Answer. The principal disadvantage of a dynamotor for this class of service is that it delivers a single voltage which cannot be regulated or changed as would be possible with a motor generator. Since only one field is used in common for both the motor and generator functions, any change in the field current would change speed and seriously effect the load-voltage characteristics of the machine. However, in service a noticeable change in field current may be expected at times because of the use of storage batteries for power supply, and their state of charge may vary considerably under different conditions of operation. Another disadvantage of a dynamotor is its poor voltage regulation under varying loads; the voltage generated by a dynamotor without load is comparatively very much higher over the voltage on load than for similar conditions in a motor-generator set.

6.16. *Question.* How may the output voltage of a dynamotor be regulated?

Answer. By varying the input voltage applied to the dynamotor. This is not a very efficient means since it affects the speed-load characteristics.

6.17. *Question.* What is the line current of a single-phase, 7-horsepower a-c motor when operating from a 120-volt line at full rated load and at a power factor of 0.8 and 95 per cent efficiency?

Answer. The line current is 57.2 amperes.

Computation: First step is to convert 7 horsepower to electrical power, or watts; next step is to find the power in watts at 95 per cent efficiency; last step is to use the wattage value just found together with the given voltage and power factor values to determine the line current. The three steps are worked out as follows:

(1) $$P = 7 \text{ horsepower} = 7 \times 746 = 5{,}222 \text{ watts (rated load)}$$

$$P_e = \text{electrical power} = \frac{\text{mechanical power}^*}{\text{efficiency}}$$

(2) $$P_e = \text{electrical power} = \frac{5{,}222}{0.95} = 5{,}490 \text{ watts}$$

$$P_e = EI \cos\theta = 5{,}490$$

(3) $$I = \frac{5{,}490}{E \times \cos\theta} = \frac{5{,}490}{120 \times 0.8} = 57.2 \text{ amperes}$$

* Stated another way: $P_{\text{input}} = \dfrac{P_{\text{output}}}{\text{Efficiency}}$

6.18. *Question.* What is the effect of an inductive load on the output voltage of an alternator?

Answer. The output voltage of an alternator will be decreased with an inductive load.

6.19. *Question.* What is the principal advantage in the use of a dynamotor rather than a motor generator to furnish plate power to a small mobile transmitter?

Answer. The compactness of a dynamotor is its chief advantage over a motor generator. A dynamotor has only one field and one armature on which is placed the input and output windings whereas a motor generator consists of two separate units comprising two fields and two armatures.

6.20. *Question.* Define "voltage regulation."

Answer. The voltage regulation of a direct-current generator is the final change in voltage with constant field rheostat setting when the specified load is reduced gradually to zero, expressed as a per cent of rated load voltage, the speed being kept constant. (A.I.E.E. definition.)

Note. In practice it is often desirable to specify the over-all regulation of the generator and its driving machine, thus taking into account the speed regulation of the driving machine. (See the answer to Question 3.121 for the voltage regulation formula.)

6.21. *Question.* What means may be used to measure radio-frequency current?

Answer. The hot-wire ammeter and thermocouple ammeter are two instruments which will measure radio-frequency current.

6.22. *Question.* How may the range of a thermocouple ammeter be increased?

Answer. The indicating range of the meter attached to a thermocouple may be increased by inserting a voltage dropping resistor in series with the meter connection. Ordinarily it is not advisable to use resistance shunts or current transformers at the thermocouple itself to accomplish this purpose, although it may be done. Another method is to connect a low capacitance in series with the thermocouple and then connect this combination across a high capacitance which is in series with the circuit.

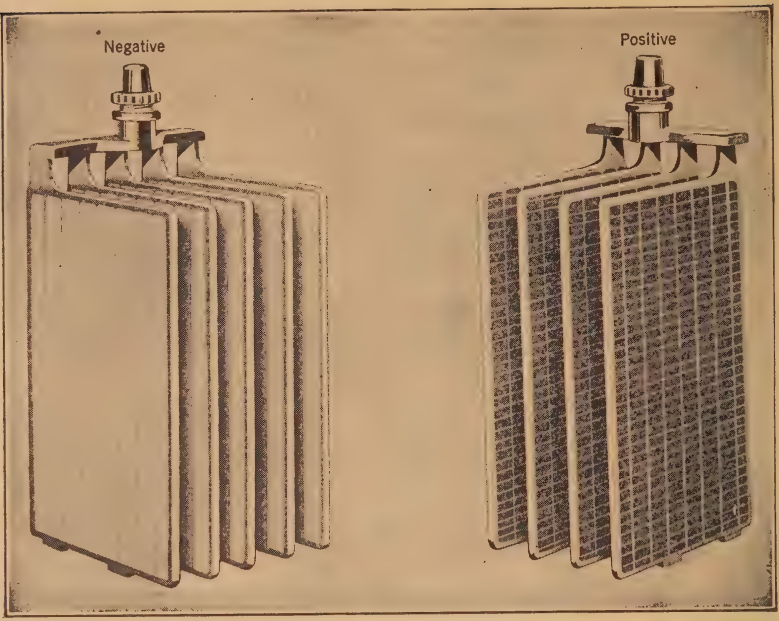


Fig. 103*a*. The negative and positive plates of the type MVA Exide cell.

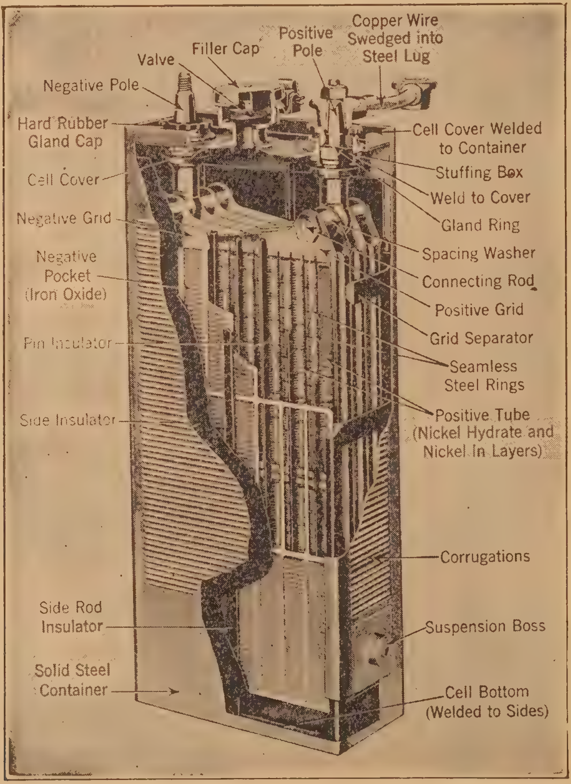


Fig. 103*b*. Cross-sectional view of the Edison storage cell.

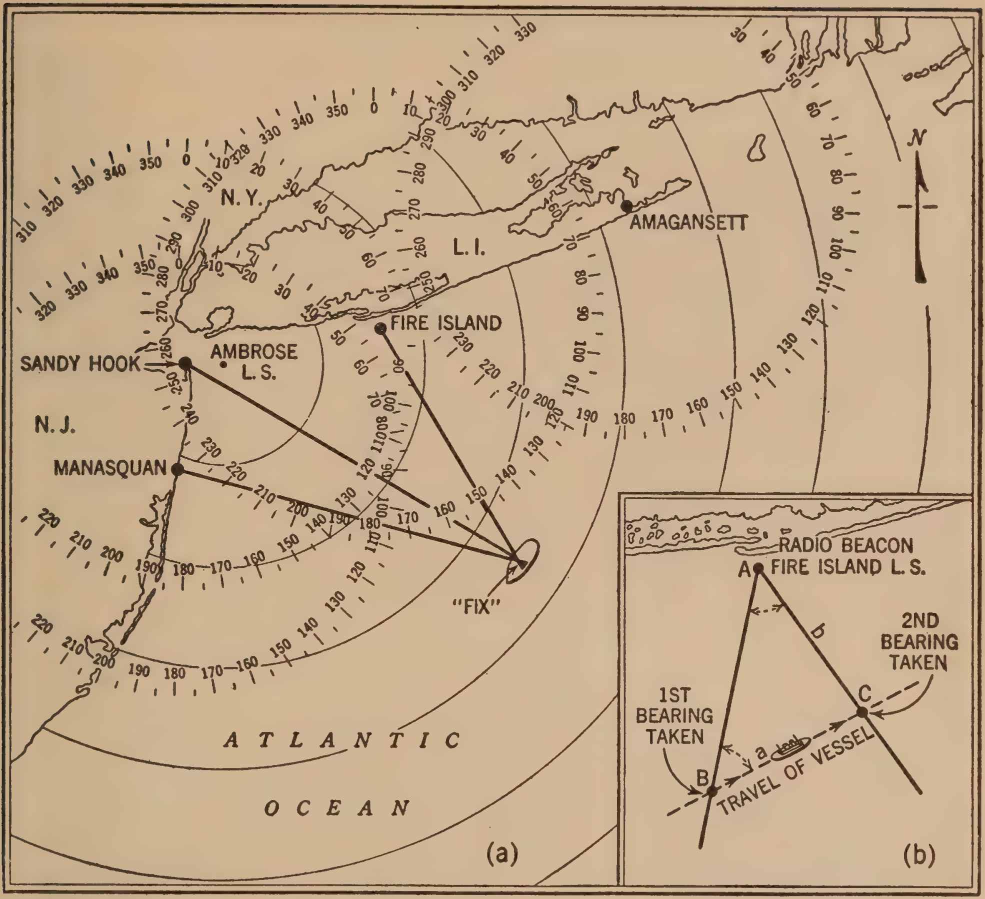


FIG. 104. (*a*) Illustrating method used to furnish a bearing to a vessel not equipped with direction-finding equipment. The map shows the New York harbor entrance group of direction-finder stations maintained by the United States Navy. The position of a vessel is plotted from three cross-bearings taken simultaneously by these shore stations on signals sent out by the ship's transmitter. The center of the small triangle usually formed where the lines intersect is known as the "fix" and is considered to be the position of the vessel. (*b*) With direction-finding equipment aboard a vessel its position can be plotted by taking bearings on two or three radiobeacon stations maintained by the United States Lighthouse Service. Radiobeacon stations in New York harbor and vicinity are the Ambrose Lightship, Fire Island Lightship, Scotland Lightship, and Barnegat Lightship. The small sketch illustrates the principle applied to obtain a bearing on a single radiobeacon station. By forming a triangle in which two angles, A and B, are known from two bearings taken at intervals, and one side a is also known, because it is the distance in miles traveled by the ship in the time between the taking of the bearings, then the other side b, or the distance between the radiobeacon station and the vessel, is found by solving for b in following equation, where

$$b = \frac{a \cdot \sin B}{\sin A}$$

Calls of stations: Fire Island (master station NJY), Sandy Hook (NHD), Manasquan (NFK).

6.23. *Question.* Does the scale of an a-c ammeter indicate peak, effective, or average current values? Explain your answer.

Answer. An a-c ammeter indicates *effective* value. The force tending to rotate the moveable coil at any instant is proportional to the square of the current flowing at that instant. However, the inertia of the coil prevents it from following the rapid current changes between zero and peak values and actually the coil moves up to a position determined by the *average value of the deflecting force.* Since the deflecting force depends upon the value of the current squared, as already stated, the movement of the coil and its pointer will be proportional to the effective value of the current.

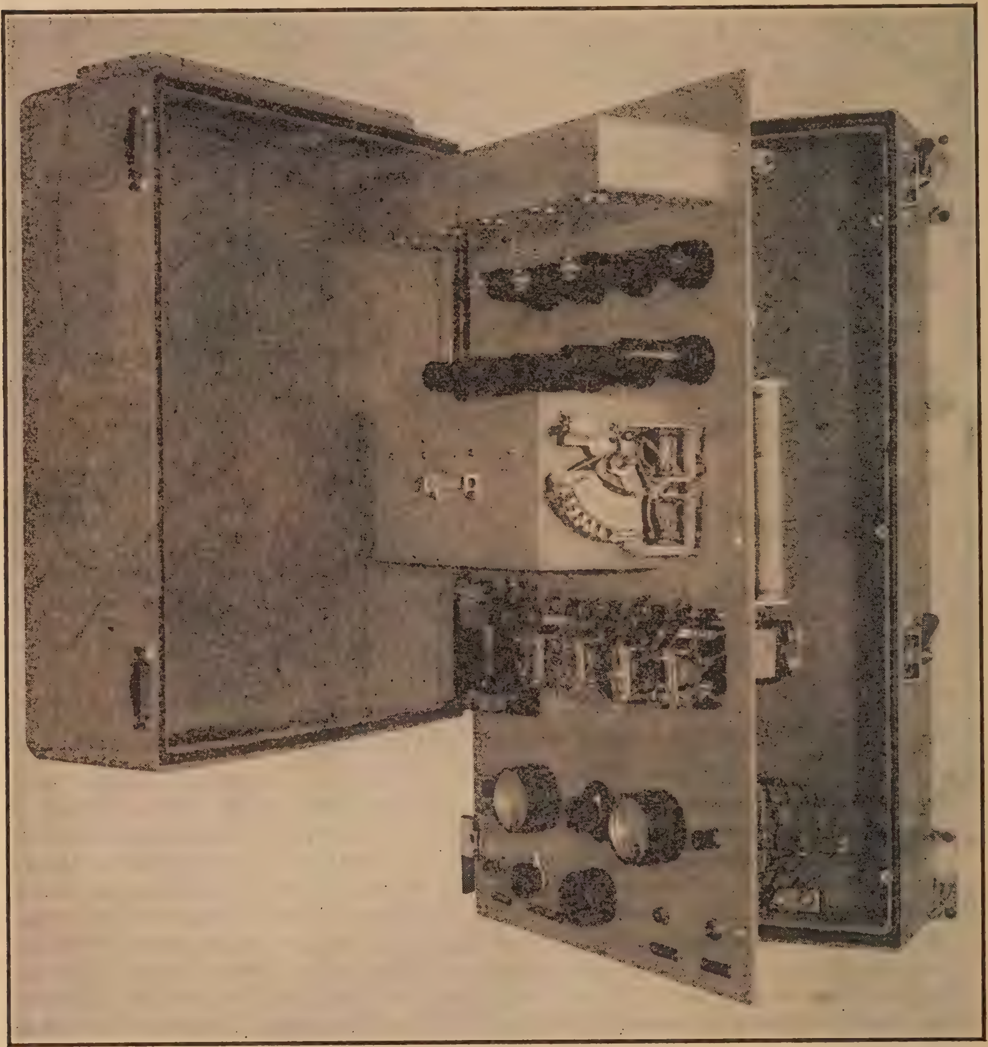


FIG. 105. A type of auto-alarm shown with cover and front panel open. (*Courtesy of Radiomarine Corporation of America.*)

6.24. *Question.* How may the power in an a-c circuit be determined?

Answer. The power in an a-c circuit may be determined by the use of a wattmeter. Also, if the power factor of the circuit were known this value could be multiplied by the product of the current and voltage readings to determine the power.

6.25. *Question.* A ship's transmitter has an antenna current of 8 amperes using A1 emission. What would the antenna current be when this transmitter is 100 per cent modulated by sinusoidal modulation?

Answer. 9.8 amperes.

Calculation: Without modulation the antenna current is 8 amperes and with 100 per cent modulation it will increase 22.5 per cent, or $1.225 \times 8 = 9.8$ amperes.

6.26. *Question.* The d-c plate input to a modulated class C amplifier with an efficiency of 60 per cent is 200 watts. What value of sinusoidal audio power is required in order to ensure 100 per cent modulation? 50 per cent modulation?

Answer. An audio power of 100 watts is required for 100 per cent modulation and 25 watts for 50 per cent modulation.

Calculation: The formula below gives the relation between (1) the audio power necessary to produce the side-bands which convey the intelligence, indicated as side-band power, P_{sb}, (2) the d-c plate input to the modulated r-f amplifier necessary to produce the carrier and including power dissipated in the plate, indicated as carrier power, P_c, and (3) the percentage of modulation, indicated by the modulation factor, m. For 100 per cent modulation $m = 1$, and for 50 per cent modulation $m = 0.5$.

$$P_{sb} = \frac{m^2}{2} P_{\text{INPUT}}$$

Problem 1. Let P_c equal 200 watts and m equal 1. Then

$$P_{sb} = \frac{1^2}{2} \times 200 = \frac{1}{2} \times 200 = 100 \text{ watts, audio power}$$

Problem 2. Let P_c be equal to 200 watts and m equal 0.5. Then

$$P_{sb} = \frac{0.5^2}{2} \times 200 = \frac{0.25}{2} \times 200 = 25 \text{ watts, audio power}$$

6.27. *Question.* What increase in antenna current will be observed when a radiotelephone transmitter is modulated 100 per cent by a sinusoidal wave form?

Answer. The increase will be 22.5 per cent, or 1.225 times the unmodulated value.

6.28. *Question.* What is the total band width of a transmitter using A2 emission with a modulating frequency of 800 cycles and a carrier frequency of 500 kilocycles?

Answer. The band width is 1,600 cycles.

Computation: In this example, during modulation the upper and lower side-band frequencies, respectively, are equal to $500{,}000 + 800$ and $500{,}000 - 800$, and the sum of these two side-bands represents the band width. In other words, the band width extends 800 cycles above the carrier and 800 cycles below it, or a total of 1,600 cycles.

6.29. ***Question.*** **What are the general characteristics of the emission of a radiotelegraph transmitter which uses a chopper to obtain A2 emission?**

Answer. While the sending key is closed the continuous wave being generated is interrupted, or broken up, into groups of oscillations of constant amplitude which provide the tone frequency, that is, the group frequency is an audible frequency. With the chopper wheel running and the key closed each time a commutator segment "makes" with the brush a group of oscillations of constant amplitude is radiated, and with each "break" when the brush contacts an insulating bar there is a silent period. Hence the rate at which the oscillations are being interrupted provides the tone frequency. This type of emission is known as ICW, interrupted continuous wave.

6.30. ***Question.*** **How should the bias of a grid modulated radio-frequency stage be adjusted?**

Answer. The grid bias should be adjusted at such a value that crest (full) modulation voltage drives the bias just to cutoff. Therefore, at the crest of the modulation voltage cycle the stage at that instant is operating essentially class B, and at the trough of the modulation cycle the plate current goes just to zero. Thus a grid modulated r-f amplifier operates class C and the amount of the cutoff bias is adjusted to equal the peak voltage of the modulation wave. The usual statement places the value of the bias voltage at about 2 times plate-current cutoff; however, it may be 3 or 4 times cutoff by design.

6.31. ***Question.*** **Compare the characteristics of plate and grid bias modulation.**

Answer. The main characteristics of plate versus grid bias modulation are listed as follows:

Plate modulation.

High efficiency.
Plate voltage varied by the audio voltage.
Grid bias voltage more or less constant; actually the bias varies a little in a properly designed stage.
Comparatively easy to adjust.
Grid r-f excitation kept constant.
Comparatively large audio power required.

Grid bias modulation.

Low efficiency.
Grid bias voltage varied by the audio voltage.
Plate voltage kept constant.
Grid r-f excitation voltage kept constant.
Comparatively low audio power required.

6.32. ***Question.*** **Is a high degree of modulation desirable in connection with a self-excited type of transmitter? Explain.**

Answer. No. In a self-excited type of transmitter it would be necessary to modulate the oscillator. As a result the carrier frequency would vary badly during modulation if a reasonably large audio power were applied either in the grid or plate circuits. It would be necessary to use a very small audio voltage, and this means low percentage modulation.

6.33. ***Question.*** **What is meant by "low level" modulation?**

Answer. Low level modulation is modulation produced at a point in a system when the power level is low compared with the power level at the output of the system. (F.C.C. Rules and Regulations 2.32.)

6.34. ***Question.*** **Why is a series resistor used in the d-c plate supply of a modulated radio-frequency amplifier, between the amplifier and the modulator, in a Heising modulation system?**

Answer. The series voltage dropping resistor in the r-f amplifier plate supply is used so that 100 per cent modulation may be obtained from the Heising modulation system. In this system the modulator and the modulated amplifier receive their plate voltage from a common power supply, and allowing for losses it would be impossible to effect 100 per cent modulation if both plates were operated at exactly the same voltage. The voltage on the modulated amplifier plate is dropped to a value of about two-thirds the supply voltage which is applied to the modulator plate.

6.35. ***Question.*** **Should the efficiency of a grid bias modulated stage be maximum at complete modulation or zero modulation? Explain.**

Answer. The efficiency should be maximum at zero modulation. The explanation for this statement is that the grid bias is more negative at zero modulation than at full modulation, and in class C operation as the bias is made more negative the angle of plate current flow decreases (narrows), which means greater stage efficiency.

Discussion. A grid bias modulated stage is operated class C and the value of the bias voltage applied beyond cutoff may be adjusted to equal the peak (crest) voltage of the audio wave. Therefore, the audio voltage wave will cause the bias to become minimum or the same as cutoff value on positive peaks (crest) of the wave, maximum on the negative peaks (trough), and resume normal operating value on the zero points. Also, in class C operation, as the bias becomes larger it results in shorter pulses of plate current, referred to as the *angle of plate current flow.* Furthermore, the efficiency varies according to the angle of plate current flow, the efficiency being higher for a smaller angle (shorter plate current pulses resulting from increased bias) and lower for a wider angle (longer plate current pulses resulting from decreased bias). Consequently, as the bias is made more negative in a class C stage the angle of plate current flow decreases (narrows), and this means greater stage efficiency; but this type of operation necessitates large excitation (r-f driving) voltage. Then on the contrary, as the bias is made less negative on positive swings of the audio wave the efficiency decreases. It will be lowest at the peak (complete modulation) because at that moment the bias is at cutoff value with the stage operating essentially class B.

Notes on efficiency. The following tabulations are given to suggest how the efficiency varies at different points of an audio wave in a grid bias modulated stage. The points on the audio cycle selected for illustration below are (1) the peaks of the positive swings, or crest, (2) the zero points at which no modulation occurs, and (3) the peaks of the negative swings, or trough.

(1) At maximum (complete) modulation, or *crest,* the efficiency is that of a class B stage.
(2) At no modulation, *zero,* the efficiency is that of a fair class C stage.
(3) At minimum modulation, or *trough,* the efficiency is that of a good class C stage.

The following list of values gives the theoretical maximum efficiencies compared with actual efficiencies that may be expected for each of the above three conditions.

			Approximate
(1) Theoretical maximum efficiency	78.5%	Actual efficiency	55%
(2) Theoretical maximum efficiency	100%	Actual efficiency	65%
(3) Theoretical maximum efficiency	100%	Actual efficiency	75%

6.36. *Question.* What is the purpose of the plate choke used in Heising modulation?

Answer. The plate choke in a Heising modulation system is used to build up a reactance voltage at the audio frequencies which is shunt fed to the plate of the modulated r-f amplifier.

Discussion. The choke possesses an infinite amount of reactance for the lowest audio frequencies to be handled, and it is connected in the positive high-voltage lead which is common to both the modulator and modulated r-f amplifier plates. Under these conditions the d.c. supplied to both plates by the power supply is kept substantially constant by the choke, which accounts for this method of modulation being known also as the *constant current system.* With audio excitation applied, the plate currents in the modulator and modulated amplifier tubes are inversely proportional to each other. For example, on a positive swing of audio excitation the modulator plate current increases a certain amount but the modulated amplifier plate current decreases by a like amount, which keeps the total current unchanged through the choke. Therefore as the modulator plate current varies with audio excitation the action of the choke in tending to prevent these changes through it builds up a reactance voltage which is applied in shunt to the modulated r-f amplifier plate. Thus the action of the choke provides the audio voltage which modulates the plate circuit of the r-f amplifier.

6.37. *Question.* Does grid current flow in the conventional grid bias modulated stage of a radiotelephone transmitter under modulated conditions?

Answer. Yes. The stage may be adjusted to allow a small grid current to be drawn on the high positive peaks of audio excitation.

6.38. *Question.* If the first speech amplifier tube of a radiotelephone transmitter were overexcited, but the percentage modulation capabilities of the transmitter were not exceeded, what would be the effect upon the output?

Answer. The effect on the output would be positive carrier shift and distortion.

Discussion. The first speech amplifier normally gives a linear output but overexcitation would result in amplitude distortion. This distortion would be greatly amplified in passing through the audio stages, and therefore a badly distorted wave form would go to the modulated r-f stage. The overloading of an amplifier due to overexcitation causes the distortion to be carried through the whole system.

6.39. *Question.* What types of microphones have a high impedance output?

Answer. Condenser and crystal microphones have a high impedance output.

6.40. *Question.* What are the advantages of the single-button carbon microphone?

Answer. The proper button current can be obtained readily for the single-button type as compared with a double-button microphone in which the button current must be carefully balanced. A microphone transformer with center-tapped primary is not required with the single-button type.

6.41. *Question.* Why is a "speech amplifier" used?

Answer. A speech amplifier consists of several audio stages operating as voltage amplifiers used to raise the gain of a low-level signal from a microphone circuit to a higher level. The output of a speech amplifier may be used for a number of purposes, such as to feed an audio line, drive a modulator stage, or supply input to a bridging amplifier for driving a loudspeaker.

6.42. *Question.* What might be the causes of a positive shift in carrier amplitude during modulation?

Answer. Positive carrier shift means that the amplitudes of the positive halves of the modulated r-f carrier are greater than the negative halves, and consequently the carrier power shifts upward. The following might cause this condition:

Insufficient r-f excitation.
Excessive grid bias on r-f amplifier.
Poor regulation of bias supply.
Detuned circuits.
Overmodulation; overmodulation may cause either a positive or negative carrier shift.
Modulator stage; excessive bias or insufficient excitation.

6.43. *Question.* What is the ratio between the d-c power input of the plate circuit of the stage being plate modulated and the output audio power of the modulator for 100 per cent sinusoidal modulation?

Answer. The ratio is 2:1, that is, the d-c power input to the plate of the modulated r-f stage is twice the audio power of the modulator.

6.44. *Question.* At 100 per cent amplitude modulation, what is the ratio of peak antenna current to unmodulated antenna current?

Answer. The ratio is 2:1. That is, the peak value when modulated 100 per cent is double the carrier peak value when unmodulated.

6.45. *Question.* At 100 per cent amplitude modulation, what is the ratio of peak antenna power to unmodulated antenna power?

Answer. The ratio is 4:1. That is, the peak antenna power at 100 per cent amplitude modulation is four times the antenna (carrier) power when unmodulated.

6.46. *Question.* Using a regenerative receiver, without radio-frequency amplifier stages, describe how you would adjust to receive radiotelegraph signals through interference.

Answer. To receive through interference, adjust the receiver for loose coupling and if the signal is of the A2 type then set the regeneration control just below the point where the detector goes into oscillation. Now tune the primary and secondary circuits carefully, and gradually make readjustments in the coupling followed by retuning for each coupling change until the peak of the desired signal is sharpened and made slightly stronger than the interfering signals. A slight readjustment of the regeneration control may improve the sensitivity and selectivity. Final critical adjustments may be made if necessary, but for any change of coupling the primary and secondary should be carefully retuned to keep these circuits in resonance. If the desired signal is of the A1 type the foregoing procedure should be used except that the detector should be set into oscillation by advancing the regeneration control.

6.47. *Question.* **What is the effect upon the sound of received type B emission if the receiver detector is oscillating?**

Answer. A signal from a spark transmitter comes in with a "mushy" tone, and in some cases it may be difficult to distinguish between the dots and dashes if the receiver detector is oscillating.

6.48. *Question.* **What effect does an incoming signal have upon the plate current of a triode detector of the grid-leak type?**

Answer. An incoming signal causes the plate current to undergo an average change which is below the normal value.

6.49. *Question.* **If broadcast signals interfered with your reception of signals on 500 kilocycles while aboard ship, how would you reduce or eliminate such interference?**

Answer. Connect a series-rejection type of wave-trap in series with the antenna lead-in to the receiver and tune the wave-trap to the frequency of the interfering signals. (See Figure 30.)

Discussion. The series-rejection wave-trap is a parallel resonant circuit consisting of a coil and a variable condenser. When tuned to the interfering signal frequency it will have maximum impedance at this frequency, but other frequencies will pass through it and flow in the antenna circuit of the receiver. Frequencies below the frequency at which the wave-trap is tuned pass through the inductance branch of the combination since its reactance is less for these frequencies, and frequencies above the wave-trap frequency pass through the capacity branch as its reactance decreases at the higher frequencies.

6.50. *Question.* **Describe how you would test a regenerative receiver to determine if the detector is in an oscillating condition.**

Answer. If the regeneration control is retarded while a regenerative detector is oscillating, a sound, best described as a "plop," will be heard in the headphones when the detector is taken out of oscillation. Another test that will indicate oscillation is to touch the finger to the grid lead or grid terminal of the detector socket and again the familiar "plopping" sound will be heard as the detector stops oscillating.

6.51. *Question.* **Discuss the relative advantages and disadvantages of a stage of radio-frequency amplification as compared with a stage of audio-frequency amplification for use in connection with a regenerative detector.**

Answer. In general a stage of radio-frequency amplification is preferable because it increases the selectivity and sensitivity of the receiver, besides acting to isolate the detector from the antenna, which prevents radiation of an interfering wave when the detector is in an oscillating condition. The tuning requirements are increased by the addition of an r-f stage. The advantage of an audio-frequency stage is that it is capable of building up a stronger signal, that is, providing a greater gain per stage, than is possible in an r-f amplifier. For headphone reception a stage of r-f amplification is more desirable, but if a loudspeaker were to be used an audio stage would answer best.

6.52. *Question.* **If a ship's regenerative receiver failed to oscillate when**

the regeneration control was advanced, explain the possible causes and remedies.

Answer. On the assumption that an A2 signal could be received, the most likely causes for non-oscillation in a marine type of regenerative receiver are: low plate voltage, low filament voltage, low emission detector tube, and defective oscillation test switch. The remedies are obvious. Replace a low "B" battery with a fresh one, recharge filament battery, replace detector tube with a good spare, and correct defective switch action. A commercial marine type receiver may be provided with an oscillation test switch which might be stuck closed and thus keep the tickler coil short-circuited.

6.53. ***Question.*** **Explain how you would test the various components of a receiver of the three-circuit regenerative type in "trouble shooting."**

Answer. The various components of a three-circuit regenerative receiver are itemized below with suggestions for testing, which consists essentially of checking for opens, shorts, and grounds. The list also includes tubes, batteries, headphones, and antenna and ground connections. A continuity meter made up of a voltmeter and battery in series, or headphones and battery, would serve generally to check for the more common troubles. An ohmmeter could be used to check for normal resistance values and also for continuity checking.

(*a*) **Three-circuit tuner** Primary, secondary, and tickler coil can be checked for continuity, which should include each tapped switch point. Check pigtail connections on the antenna coupling coil and tickler coil for a possible break which may be hidden beneath the cotton loom which is generally used to enclose the flexible wire. The continuity of the grid circuit could be checked from the connections at the filament and to the grid-leak. Continuity of the entire plate circuit could be checked from the plate terminal of the detector tube socket to the +B battery connection; this check includes the tickler coil and primary of the first audio transformer.

(*b*) **Tuning condensers.** Check for a warped condenser plate that may rub and short-circuit and for imperfect electrical contact to the rotor element.

(*c*) **Audio transformers.** The primary and secondary windings would be tested separately for possible break in the wire; the continuity meter would indicate "open" for this trouble.

(*d*) **Grid-leak and condenser combination.** A defective grid-leak could be tested for an open-circuited condition with headphones and battery in series, using a 45-volt "B" battery in this case. The condenser could be checked by the click method, using phones and battery as follows: a good condenser will be charged when the test circuit is connected across it as indicated by a click in the phones, and then by opening and closing the test circuit several times in quick succession the click will diminish in strength each time contact is made and will finally become barely audible when the condenser has a full charge. A shorted condenser will give a loud click each time contact is made and no click if open-circuited.

(*e*) **Rheostats.** Examine rheostats for proper contact pressure on the resistance wire.

(*f*) **Switches.** Check switch blades and contact studs for proper contact and for proper spring tension so as not to permit unnecessary wear and cutting into the contact surfaces. Check oscillation test switch to see that it operates freely and will not stick closed, causing the tickler coil to be short-circuited.

(*g*) **Headphones, cords, jacks.** Check for open in phone windings, weak magnets, broken strands of the fine tensil wire in the phone cords, and examine phone jacks for proper contact and action between spring leaves.

(*h*) **Antenna safety gap, antenna and ground connections.** A commercial type regenerative receiver is provided with a protective spark gap connected between antenna and ground which might become short-circuited; check the gap and use a thin card to clear it of any accumulation of dust or dirt. Examine the strap or clamp where the *actual* ground connection is made and clean and tighten if necessary. Check the antenna lead-in to the antenna post.

(*i*) **Soldering and wiring.** A cold-soldered joint or a corroded connection somewhere in the r-f circuits might cause trouble due to the forming of a very high r-f resistance, which is often difficult to locate. Ordinary continuity checking usually will not detect this condition. If this seems to be the trouble, it is best to resolder and remake all such connections in the hope of finding the faulty one.

(*j*) **Batteries.** A common source of trouble is a low "B" battery or worn out "C" battery. If a 45-volt "B" battery has dropped to about 37 volts it should be replaced with a fresh one and at the same time replace the "C" battery, always renewing them together. The filament storage battery should be checked as a possible source of trouble.

(*k*) **Tubes and tube sockets.** A low emission tube will give trouble. If the condition of the tubes is doubtful they should be replaced with spare tubes known to be good. Trouble may result if the pins in the tube base make poor contact in the socket; clean the parts with fine sandpaper if corroded and check for proper spring tension.

Note. The foregoing list does not suggest any order of sequence in "trouble shooting" since this differs according to the symptoms, but in the case of an inoperative receiver or failure to oscillate the tubes and batteries or power supply voltages ordinarily would receive first consideration.

6.54. ***Question.*** **What is the effect of connecting a high value of resistance in parallel with the primary of an audio transformer in a regenerative receiver?**

Answer. A high resistance across the primary of the audio transformer will eliminate *fringe howl.* The howl may be produced by the plate load impedance returning energy to the oscillations in the proper phase at the most sensitive adjustment of regenerative feedback and the purpose of the resistor is to make the load impedance less inductive. The value of the resistance should be equal approximately to the plate resistance of the tube.

6.55. ***Question.*** **Why should a superheterodyne receiver, used for the reception of A1 signals, be equipped with at least one stage of radio-frequency amplification ahead of the first detector?**

Answer. The r-f stage will reduce image frequency response and prevent radiation of the local generated frequency. Selectivity and sensitivity are both improved by the use of the r-f stage.

6.56. *Question.* **What is the chief advantage to be gained in the utilization of high intermediate frequencies in a superheterodyne receiver?**

Answer. The possibility of image-frequency response is reduced.

6.57. *Question.* **If a superheterodyne receiver is receiving a signal on 1,000 kilocycles and the mixing oscillator is tuned to 1,500 kilocycles, what is the intermediate frequency?**

Answer. The intermediate frequency is 500 kilocycles, or the difference between the oscillator and signal frequencies.

6.58. *Question.* **Why are diode detectors usually employed in modern radio receivers?**

Answer. A diode detector has several desirable features as follows: it operates with an almost perfect linear characteristic, giving excellent reproduction of the signal wave shape with small distortion; it can handle comparatively large signal power; and it is adaptable for use with automatic volume control (avc) and automatic frequency control (afc) circuits.

6.59. *Question.* **What is the purpose of an auxiliary receiving antenna installed on a compulsorily equipped vessel which is also fitted with a direction finder?**

Answer. The auxiliary antenna connects to the ship's receiver and enables the operator to maintain the compulsory listening watch on 500 kilocycles, distress wave, twice each hour for three minute periods irrespective of whether the direction finder may be in use during those periods.

6.60. *Question.* **What is the primary purpose of a "break-in" relay associated with a radiotelegraph transmitter?**

Answer. A break-in relay provides a means for rapidly changing from transmission to reception and vice versa, which enables the operator at the sending station to listen-in during the rapid succession of spacing periods while sending. Hence, it is possible for the operator at the sending station to receive a signal from the station receiving that would indicate interference encountered or a request for repeat without necessarily waiting for the end of traffic. The relay contacts are adjusted so that each time the operator's key is in the "up" position the receiver is connected to the antenna.

6.61. *Question.* **When an antenna is erected, why should precautions be taken to prevent the wire from kinking?**

Answer. A kinked wire is likely to break when subjected to a strain. A slight change in electrical characteristics might result from a kinked wire.

6.62. *Question.* **What may be the cause of noisy operation of a regenerative, three-circuit receiver having two stages of audio-frequency amplification?**

Answer. Noisy operation may be caused by the following: run down "B" and "C" batteries, poor antenna and ground connection, leaky bypass condenser, defective tube, defective audio transformer, defective grid leak, loose or poorly soldered connections, excessive "A" or "B" voltages, imperfect electrical contact at rotor of variable condenser, excessive tickler coupling, critical regeneration adjustment, and moisture within the set.

6.63. *Question.* How may the frequency of the antenna circuit of a shipboard receiver be lowered?

Answer. By increasing the inductance of the antenna circuit, for example, by connecting an inductance in series or by increasing the number of turns in a tuning inductance already connected. If an antenna tuning condenser were provided its capacitance should be increased to accomplish the same purpose.

6.64. *Question.* How may the frequency of the antenna circuit of a shipboard receiver be increased?

Answer. By decreasing the inductance of the antenna circuit, for example, by using less turns at the antenna tuning coil. Also, by decreasing the capacitance of the antenna tuning condenser.

6.65. *Question.* What is the directional reception pattern of a loop antenna?

Answer. A loop antenna gives a *figure-of-eight* pattern with the line of direction of the signal wave in a plane with the loop. See Figure 106.

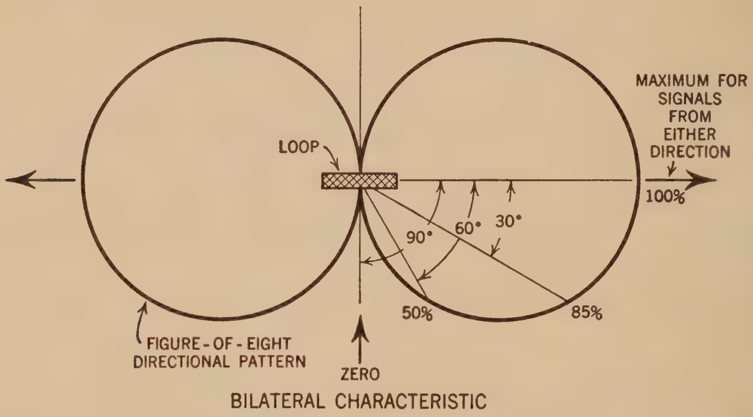

MAXIMUM FOR SIGNALS FROM EITHER DIRECTION
LOOP
100%
90°
60°
30°
50%
85%
FIGURE-OF-EIGHT DIRECTIONAL PATTERN
ZERO
BILATERAL CHARACTERISTIC

FIG. 106. The bilateral directional pattern consists of two large circles.

6.66. *Question.* What is the directional reception pattern of a vertical antenna?

Answer. The pattern is a *concentric circle* with the antenna as the axis. See Figure 107.

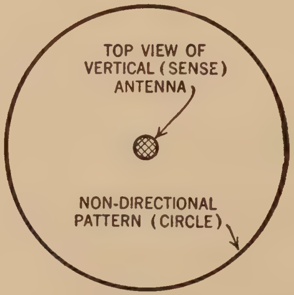

TOP VIEW OF VERTICAL (SENSE) ANTENNA
NON-DIRECTIONAL PATTERN (CIRCLE)

FIG. 107. The non-directional pattern consists of a circle.

6.67. *Question.* What is meant by "split tuning"?

Answer. "Split tuning" is an effect resulting from tight coupling between two radio-frequency circuits which may cause the operating frequency suddenly jumping to some other frequency. The response curve for a condition of close coupling has two pronounced peaks, or double humps, indicating two frequencies differing by a relatively large percentage.

6.68. *Question.* Why should a transmitter be adjusted at reduced power?

Answer. Adjusting a transmitter at reduced power is a safety measure because when operating detuned plate circuits at full power the plate current may rise to abnormally high values, which could ruin tubes and damage component parts. The plate current may be kept within safe limits by using low power when making adjustments.

6.69. *Question.* How is the power output of a marine vacuum tube radiotelegraph transmitter ordinarily adjusted?

Answer. The minimum amount of power necessary to ensure reliable communication should be used at all times. A generator field rheostat is used to control the amount of power.

6.70. *Question.* A marine transmitter uses 500-cycle alternating current for plate supply. It is rectified by a full-wave rectifier circuit but is not filtered. How would the emission be classified?

Answer. A2 emission.

6.71. *Question.* In general, what advantages may be expected by the use of high frequencies in radio communication?

Answer. Signals covering great distances may be obtained from compact transmitters operating on comparatively low power; relatively small antenna systems are used.

6.72. *Question.* How is the antenna aboard ship changed most rapidly from the transmitter to the receiver during the course of communication?

Answer. By the use of a break-in relay. .

Discussion. One type of break-in relay employs three pairs of contacts which function as follows: When the sending key is *up* one pair opens and applies high blocking voltage to stop oscillation, another pair opens the antenna to ground circuit, and the third pair closes and connects the antenna to receiver input. When the sending key is *down* the functions are reversed, that is, grid blocking bias is removed and oscillations are generated, the antenna is connected through to ground, and the input to the receiver is short-circuited.

6.73. *Question.* How can you determine the optimum coupling between the closed circuit of a spark transmitter and the antenna circuit?

Answer. The coupling is tightened to a point where any further increase will not increase the antenna current. The coupling may then be loosened slightly and left at this point.

6.74. *Question.* What are the primary factors which determine the frequency of emission of a spark transmitter?

Answer. The frequency of emission of a spark transmitter is determined by the constants of the closed oscillatory circuit, principally by the L–C values and somewhat on the R of this circuit due to the gap.

6.75. *Question.* What is the best method of reducing the power output of a spark transmitter?

Answer. Reduce the voltage output of the a-c generator by increasing the resistance of the generator field rheostat.

6.76. *Question.* Why are protective condensers connected across the low potential a-c circuit of a spark transmitter?

Answer. The condensers protect low-potential transmitting apparatus from high-voltage radio-frequency surges. A device of this kind consists usually of a number of condensers connected in series with the middle leg grounded and the extreme outside leads connected across the low-potential circuits to be protected, for example, across the windings (armature and field) of the motor-generator set.

6.77. *Question.* Upon what factor(s) does the spark, or note, frequency of a spark transmitter depend?

Answer. The spark, or note, frequency depends upon the frequency of the a.c. supplied by the generator and the type of spark gap. The frequency of the a-c generator is governed by the speed of the motor which is controlled by a motor field rheostat. The note frequency will be twice the generator's frequency with the use of a quenched gap or a synchronous rotary type gap.

6.78. *Question.* What factors determine the output frequency of a marine arc type radiotelegraph transmitter?

Answer. The frequency depends upon the constants of the antenna system which include: antenna capacitance, antenna inductance, antenna loading and tuning inductance, variometer, and series (short-wave) condenser. The last two tuning units mentioned may or may not be included, depending upon the equipment.

6.79. *Question.* Why is it essential that pure water be used in the cooling system associated with an arc transmitter?

Answer. Pure water possesses very high insulating properties, and although in actual contact with the anode and cathode it has negligible effect on the power. However, impure water would form a partial short-circuit path across the arc and the d-c generator, resulting in serious loss of power. In an extreme case impure water would ground the + high-voltage.

6.80. *Question.* What is the purpose of the hydrogen gas, liberated from the injected alcohol, in the arc chamber?

Answer. It is necessary to operate the arc in an atmosphere of hydrogen or a hydrogenous vapor in order to produce radio-frequency oscillations of high power from a comparatively low-voltage d-c supply. The burning of the arc in the hydrocarbon vapor causes ionization of the gas molecules, which greatly increases the conductivity of the gap periodically, resulting in oscillation of high amplitude.

6.81. *Question.* Describe the "back shunt" method of keying an arc transmitter.

Answer. The back-shunt method of keying operates on the principle of keeping the arc generating continuously and switching it either to the antenna system or to a local substitute oscillatory circuit through suitable relay key contacts. The substitute oscillatory circuit is the "back-shunt" circuit. When the key is *down* to send a code character the arc works into the antenna circuit, but when the key is *up* the arc is switched to the back-shunt circuit and no wave is radiated. The arc is kept from being extinguished when it is switched from one to the other of the r-f circuits by adjusting an iron plate inductor in the back-shunt circuit to provide sufficient r-f current in this circuit compared with the antenna current. Also, a delayed action of the relay contacts momentarily allows both r-f circuits to be in shunt with the arc. If the arc were left disconnected from either of these oscillatory circuits, even for a moment, the arc would go out, necessitating the striking of it again to start oscillation. (See Figure 60.)

6.82. *Question.* Of what material is the anode of a marine arc type transmitter composed?

Answer. The anode is a *copper* tip brazed to tubing through which pure water is circulated for cooling. The cathode is a *carbon* rod.

6.83. *Question.* Compare the advantages and disadvantages of a modern marine type vacuum tube transmitter and a marine type spark transmitter.

Answer. The comparative advantages and disadvantages of a modern vacuum tube transmitter and spark transmitter for marine services are listed as follows:

Vacuum tube transmitter.

Advantages:

Emits a sharper wave with less interference.
Operates satisfactorily on any frequency in the communication bands.
More efficient.
Greater communication distance for a given input power.
Fewer harmonics or off-frequency radiations.
Permits wider range of tone frequencies.
Transmission on two types of waves, A1 and A2.

Disadvantages:

Vacuum tubes and replacement requirements.
More parts and complex circuits, more sources of possible trouble.

Spark transmitter.

Advantages:

No vacuum tubes.
Fewer parts and simpler circuits.
In case of emergency the circuits can be adjusted to emit a very broad distress signal.

Disadvantages:

Emits a broad interfering wave with normal adjustment.
Inefficient.
Radiates strong off-frequency waves.
Limited for use to the low and medium frequency communication bands; cannot be used for high-frequency, or short wave, communication.
Cannot provide type A1 wave; good only for type B.

6.84. *Question.* What is meant by a "self-rectified" circuit, as employed in marine vacuum tube radiotelegraph transmitters?

Answer. A self-rectified circuit in commercial radiotelegraph transmitter applications refers to a circuit in which an a-c voltage without being filtered is applied directly to the plates of oscillator tubes which function during positive alternations of the power cycle to generate oscillations for emission. The frequency of the a-c plate supply must be such that it will provide the note, or tone, frequency of the signal.

Principle of operation. If two oscillator tubes are employed with their plates connected respectively to opposite ends of the center-tapped secondary of a power transformer the arrangement will result in each tube drawing plate current alternately for each power cycle similar to the function of the tubes in a conventional full-wave rectifier circuit. Whichever tube is active it produces a group of oscillations which vary in amplitude according to the voltage wave shape of the plate power cycle. Since two groups of oscillations are produced for each cycle of the power supply, the tone frequency for a supply frequency of 350 cycles will be 700 cycles. This type of wave is classified as type A2 emission. (See Figure 108.)

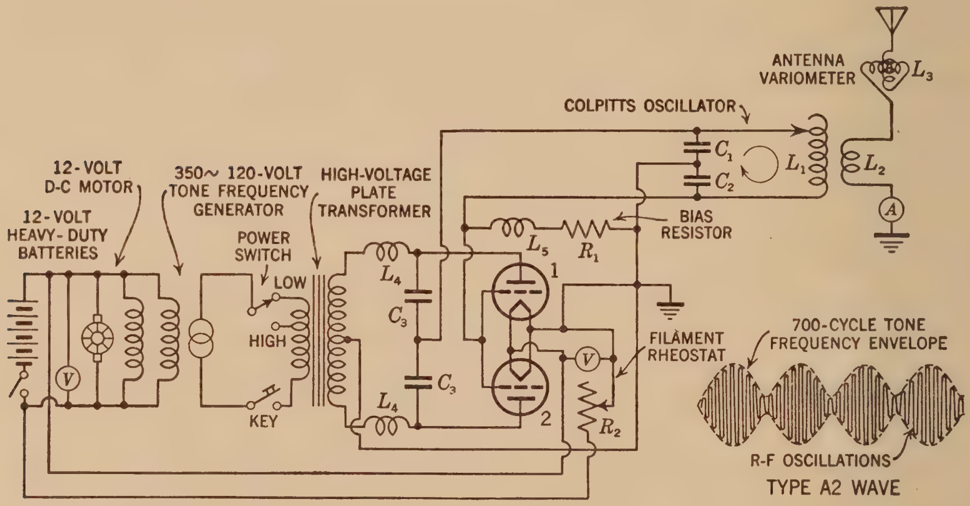


FIG. 108. Complete diagram of an emergency marine transmitter providing type A2 wave and operating from a heavy-duty 12-volt storage battery.

6.85. *Question.* What is the principal advantage to be gained by the use of a crystal-controlled oscillator in a marine radiotelegraph transmitter?

Answer. Greater frequency stability because the amount of frequency drift is kept within very narrow limits.

6.86. *Question.* Discuss the advantages and disadvantages of self-excited transmitters as compared with master-oscillator power-amplifier transmitters.

Answer. The frequency stability of a transmitter is improved by the use of a power amplifier following the master oscillator. This arrangement permits the oscillator to be worked at comparatively low power, and the desired output power may be readily obtained by means of one or more r-f amplifier stages. However, the additional parts and tubes mean more circuit adjustments and more sources of possible trouble. A power amplifier stage serves to isolate the oscillator from the antenna so that reactions on the oscillator are reduced to a minimum, for example, reactions such as might be caused by variations in antenna capacitance. In the case of a self-excited type its commercial application is limited practically to emergency radiotelegraph transmitters. Since the oscillator in this type is coupled into the antenna it is subject to heavy plate circuit load changes that may result in serious frequency instability. A few advantages of the self-excited type are less tubes, less parts, and simpler circuits.

6.87. *Question.* What is meant by the expression "motor-generator is hunting"?

Answer. Any periodic motion of the rotor of an alternator on either side of the angular position it would normally occupy is known as *hunting.* This may be brought about by the natural vibration period of the driving motor. The periodic variations in turning torque of the motor due to vibration are imparted to the alternator rotor causing a secondary movement, or oscillation as it is called, which may occur in step with the rate of variation of angular velocity of the rotor and may result in the production of a synchronizing current.

6.88. *Question.* If the automatic starter for the transmitter motor-generator failed to operate when the switch was closed, what might be the trouble?

Answer. No line voltage, blown fuse, defective, or improperly adjusted switch, open in main contactor coil of starter, defective contact bar action, insufficient brush contact with commutator, open in motor field, open in motor armature, open-circuited condition due to disconnected wires, plate overload relay may have tripped and needs resetting.

6.89. *Question.* Why is a series motor not used in radio power supply motor-generators?

Answer. A series motor has a variable speed characteristic under variable load which makes it unsuited for radio motor-generator sets; regulation would be exceptionally poor. Furthermore, such machines must operate with a load always kept applied, which is impracticable in radio power supply applications.

6.90. *Question.* If a 3-horsepower, 110-volt d-c motor is 85 per cent efficient when developing its rated output, what will be the line current?

Answer. 23.9 amperes.

Computation: First step is to convert 3 horsepower to electrical power in watts; next step is to find the power in watts at 85 per cent efficiency; last step is to use the wattage value just found together with the given voltage value to determine the line current. The three steps are worked out as follows:

(1) $$P = 3 \text{ horsepower} = 3 \times 746 = 2{,}238 \text{ watts (rated load)}$$

$$P_e = \text{electrical power} = \frac{\text{mechanical power}^*}{\text{efficiency}}$$

(2) $$P_e = \text{electrical power} = \frac{2{,}238}{0.85} = 2{,}632.9 \text{ watts}$$

$$P_e = E \times I = 2{,}632.9 \text{ watts}$$

(3) $$I = \frac{P_e}{E} = \frac{2{,}632.9}{110} = 23.9 \text{ amperes}$$

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* Stated another way: $P_{\text{input}} = \dfrac{P_{\text{output}}}{\text{efficiency}}$

6.91. *Question.* If an auxiliary storage battery has a voltage of 12.4 volts on open circuit and 12.2 volts when the charging switch is closed, what is the difficulty?

Answer. The drop in voltage indicates that the charging polarity is reversed.

6.92. *Question.* Why should an Edison storage battery not be charged at less than the normal rate specified by the manufacturer? Explain.

Answer. If the charging rate is less than the recommended value the battery will not give its rated ampere-hour capacity. The chemical reactions during charge are the oxidation from a lower to a higher oxide of nickel in the positive plate and the reduction from iron oxide to metallic iron in the negative plate. These chemical reactions are not fully realized at low charging rates.

6.93. *Question.* Lacking an hydrometer, how may the state of charge of a storage battery be determined?

Answer. A close estimate of the state of charge can be obtained by means of a voltmeter reading of a battery when on normal load. In the case of a battery being charged it can be determined with reasonable accuracy when it is fully charged by observing the gassing. A lead-acid battery charging at normal rate begins to gas freely when fully charged or nearing the completion of a charge. Of course, a small amount of gassing is expected at all times during charge, but it becomes very active at the end of the charging period and if the gassing continues this way without apparent change for about 2 hours it indicates full charge. Note that excessive, or violent, gassing due to overcharging or charging at too high a rate should not be confused with normal conditions.

6.94. *Question.* Your emergency battery has a specific gravity of 1.120. What should be done?

Answer. The battery should be put on charge immediately after first adding distilled water, or approved pure water, to the proper level.

6.95. *Question.* Why should care be taken in the selection of water to be added to a storage cell to replace that lost by evaporation?

Answer. Only distilled water, or approved pure water, should be used so as to keep out chemical or metallic impurities that would cause local action and possibly ruin the cell.

6.96. *Question.* A discharged storage battery of three cells has an open circuit voltage of 1.8 volts per cell and an internal resistance of 0.1 ohm per cell. What potential is necessary to produce an initial charging rate of 10 amperes?

Answer. The charging potential is 8.4 volts.

Solution: The charging potential must equal the voltage of the three cells plus the internal voltage drop of the cells for a 10-ampere current.

$3 \times 1.8 = 5.4$ volts, voltage of the 3 cells
$3 \times 0.1 = 0.3$ ohms, internal resistance of the 3 cells
$0.3 \times 10 = 3$ volts, internal voltage drop of the 3 cells
$5.4 + 3 = 8.4$ volts, charging potential

6.97. *Question.* What capacity storage battery is required to operate a 50-watt emergency transmitter for 6 hours, assuming a continuous trans-

mitter load of 70 per cent of the key-locked demand of 40 amperes? The emergency light load is 1.5 amperes.

Answer. The actual requirements call for a 177 ampere-hour battery. However, a standard heavy-duty battery of one type that would fill these requirements is rated at 198 to 210 ampere-hour capacity.

Solution: The ampere-hour capacity equals the sum of the light load, $6 \times 1.5 = 9$, and 70 per cent of the transmitter load, $6 \times 40 \times 0.7 = 168$, or $9 + 168 = 177$ ampere-hours.

6.98. *Question.* **Why does the charging rate to a storage cell being charged from a fixed voltage source decrease as charging progresses?**

Answer. The charging process gradually lowers the internal resistance of a cell, which raises its voltage, and, consequently, as the cell's voltage becomes higher it presents more opposition to the line e.m.f., which slightly tapers off the charging rate.

6.99. *Question.* **If you place the emergency batteries on charge and the overload circuit breakers refuse to stay closed, what is the trouble?**

Answer. The trouble might be caused by: reversed charging polarity, lack of charging voltage, charging voltage too low.

6.100. *Question.* **If part of the secondary winding of the power supply transformer of a transmitter were accidently shorted, what would be the immediate effect?**

Answer. The primary current would immediately rise to an excessive value and any possible damage probably would be prevented by overload protection in the line.

6.101. *Question.* **What are the relative advantages of the condenser-input and choke-input filter circuits?**

Answer. The condenser-input filter provides higher voltage output. The choke-input filter operates with a lower inverse peak voltage and has better voltage regulation.

6.102. *Question.* **What is the principal function of the filter in a power supply?**

Answer. The principal function of the filter in a power supply is to smooth out the pulsations of the rectified a-c cycle to provide a substantially steady d-c voltage containing only the permissible amount of ripple frequency.

6.103. *Question.* **How may the filter condenser be checked for leakage?**

Answer. A voltmeter and a direct current supply in series connection with the condenser will indicate leakage.

6.104. *Question.* **What is the maximum allowable total secondary voltage of a transformer to be used as a center-tapped full-wave rectifier in connection with rectifier tubes having a peak inverse voltage rating of 10,000 volts?**

Answer. 7,000 volts.

Discussion. In this type of rectifier the inverse peak voltage across the inactive tube is equal to the full secondary voltage, r.m.s. value multiplied by 1.41, if we neglect to consider the voltage drops in the active tube and the active section of the secondary. Hence, this problem calls for changing 10,000 volts from peak value to effective, or r.m.s., value, or 10,000 ×

0.707 = 7,070 volts. (See Figure 109.) From this simplified circuit diagram it is apparent that the total secondary voltage is applied across the two tubes in series since their cathodes are in common. Whichever tube is active when drawing current will develop a voltage drop across itself, and also there will be a voltage drop across that half of the secondary in which current flows. Therefore the inverse peak voltage across the inactive tube may be expressed as follows:

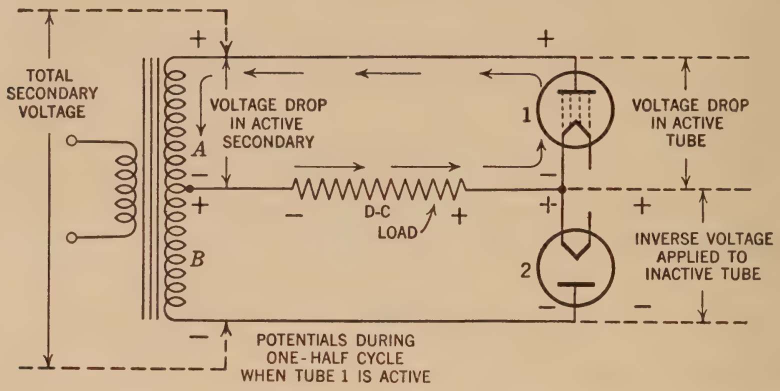
TOTAL SECONDARY VOLTAGE
+
+
VOLTAGE DROP IN ACTIVE SECONDARY
A
−
+
B
−
1
VOLTAGE DROP IN ACTIVE TUBE
−
D-C LOAD
+
+
+
INVERSE VOLTAGE APPLIED TO INACTIVE TUBE
2
−
−
POTENTIALS DURING ONE-HALF CYCLE WHEN TUBE 1 IS ACTIVE

FIG. 109. This sketch shows how a high inverse voltage is applied to the inactive tube in a rectifier.

$$E_{\text{inverse peak}} = \Big(E_{\substack{\text{total}\\ \text{secondary,}\\ \text{r.m.s.}}} - E_{\substack{\text{drop in}\\ \text{active tube}}} - E_{\substack{\text{drop in}\\ \text{active}\\ \text{secondary}}}\Big) \times 1.41$$

6.105. *Question.* Discuss the uses of copper oxide rectifiers.

Answer. One of the most common applications of a copper-oxide rectifier is its use in conjunction with d-c voltmeters for the purpose of measuring a-c voltages of low or medium frequencies. Other uses are to supply d-c fields for electrodynamic type loudspeakers and as rectifiers for battery charging equipment of the trickle charge type.

6.106. *Question.* Explain the principle of operation of the cold cathode, gaseous rectifying diodes.

Answer. The theory of *current conduction* in a gaseous type diode tube is based on the ionization of the gas from electrons which collide with or bombard the gas atoms, thus leaving the atoms in a positively charged state through losing electrons by this action. The positive atoms, or ions, seek a negative electrode to take on the same number of electrons they lost owing to ionization, whereas the electrons which were freed by collision go toward the positive electrode and represent the conduction current. The *rectification action* when utilizing a cold cathode depends for one thing upon the difference in size of the two electrodes, one electrode being much larger than the other, and also upon the difference in magnitude between a positive atom and an electron which is infinitely smaller in comparison. In this action only a relatively few electrons leave the smaller electrode in order to neutralize the more limited mass of ions around its surface, but the larger electrode does not hold such restrictions. Therefore, when an alternating-current voltage is applied to two such electrodes it results in one-way conduction, or rectification. Conduction is obtained on the half cycle when the smaller electrode is at a positive potential and the larger one at a negative potential, but when the potentials are reversed on the next half cycle, or when the smaller electrode is negative and the larger one positive, there is practically no conduction. Such a rectifier does not give 100 per cent rectification but serves effectively in practical applications.

6.107. *Question.* What are the advantages of the high vacuum rectifier tube as compared with the hot cathode gas-filled tube?

Answer. Higher maximum inverse peak voltage rating; less critical as to operating temperature; warming up period not required which obviates the need for time-delay relay equipment.

6.108. *Question.* What action permits the high conduction currents of a hot cathode gas-filled rectifier tube?

Answer. In a mercury-vapor rectifier tube the *ionization* of the vaporized gas and *neutralization* of the negative space charge are inherent characteristics which account for electrons in great quantities being made available for conduction through the tube. These actions in turn account for the tube having a low internal impedance, or low voltage drop, which is practically constant at 15 volts for all normal values of current handled by the tube. Since the voltage drop is very low and remains practically constant the I^2R loss, or dissipation, does not become excessive on high currents.

6.109. *Question.* What factor(s) determine the setting of the sensitivity control of an auto-alarm receiver approved for installation on a vessel of the United States?

Answer. The prevailing noise level, static, or radio interference are the factors that determine the setting of the sensitivity control.

Discussion. The sensitivity control should be adjusted so as not to allow the signal relay to hold over from static or interference. The proper adjustment may cause the signal relay to chatter slightly with average code signals or it may close occasionally from strong code signals or short bursts of static. If the sensitivity is set too low then a weak alarm signal may fail to operate the relay. If set too high for the prevailing average noise level and static the relay may hold over for long periods or it may chatter or vibrate steadily and the system may not respond to an actual alarm signal.

6.110. *Question.* If you were an operator on a vessel of the United States equipped with an approved type of auto alarm which employs a linear detector and an electronic selector, what factors cause the bell to sound? The warning light to operate?

Answer. The list below is divided into normal and faulty operation that would cause the bell to ring or the warning light to operate.

Sounding of bell.

Normal operation **(True Alarm):**

After reception of four dashes of a real alarm signal the bells ring.

Faulty operation **(False Alarm):**

Weak storage battery; the 6-volt battery has dropped below 4.5 volts.

Burnout of vacuum tube heater.

High- or low-line voltage; obviously this includes loss of line voltage for any reason.

Blown fuses.

False dash received; if the stepping relay had advanced three notches an unusual combination of static and ordinary code signals might advance it to the fourth notch and sound the bells.

Warning light.

Normal operation:

Warning lights operate on the first and subsequent dashes of an incoming alarm signal which gives warning before the bells ring.

Faulty operation:

Improper sensitivity adjustment may allow the signal relay to hold closed on ordinary code signals, prolonged static, or other high level noise interference.

6.111. *Question.* **If you were a radio operator on a vessel of the United States equipped with an approved type of auto alarm which employs a linear detector and an electronic selector, what would result upon failure of a vacuum tube filament?**

Answer. Ringing of the alarm bells.

6.112. *Question.* **With an auto alarm of the type which employs a linear detector and an electronic selector, what is the most probable cause of the intermittent ringing of the bells?**

Answer. The intermittent ringing of the bells most likely would be due to low, high, or variable line voltage.

6.113. *Question.* **With an auto alarm of the type which employs a square law detector and a mechanical selector, what factors cause the bell to sound? The warning light to operate?**

Answer. The causes of the bell sounding and warning light operation are as follows:

Sounding of bells.

Normal condition.

Reception of a true-alarm signal will ring bells.

Equipment failure.

Failures of the equipment which cause bells to ring include:

(*a*) Burnout of vacuum tube heater.
(*b*) Storage battery voltage too low.
(*c*) Blown fuse on battery charger.
(*d*) Motor stopped or running too slow.
(*e*) Ground on alarm bell circuit.
(*f*) Open in heater circuit.
(*g*) Open in 24-volt circuit to receiver.
(*h*) Open in 24-volt circuit to auto alarm equipment.

Warning lights.

Operation impaired.

Burning of warning lights may indicate any of the following:

(*a*) Prolonged strong interference noise.
(*b*) Prolonged heavy static.
(*c*) Sensitivity adjustment too high.
(*d*) Reception of a signal longer than 4½ seconds' duration.
(*e*) Ship's 115-volt d-c supply to receiver power supply unit has either failed or dropped below 70 volts.

6.114. *Question.* If an auto-alarm bell rings, and upon pressing the release button it does not stop, what could be the cause(s)?

Answer. The list below is a general one to include faults in the types of alarm equipment now in service.

Failure of line voltage.
High line voltage or low line voltage.
Storage battery too low.
Heater burnout of vacuum tubes.
Blown fuses.
Ground on alarm bell circuit.
Motor stopped or running too slow.

6.115. *Question.* If a ringing auto-alarm bell stops upon pressing the release button, what could be the cause(s) of the ringing?

Answer. Reception of a true auto-alarm signal.

6.116. *Question.* With an auto alarm of the type which employs a square law detector and a mechanical selector, why does this alarm receiver not respond to type A1 emission?

Answer. This alarm equipment employs a receiver of the tuned radio-frequency (TRF) type.

6.117. *Question.* From how many simultaneous directions is a direction finder capable of receiving signals if adjusted to take unilateral bearings through 360°?

Answer. From only one direction.

6.118. *Question.* What figure represents the reception pattern of a properly adjusted unilateral radio direction finder?

Answer. A cardioid. The heart-shaped curve in Figure 110 illustrates a cardioid.

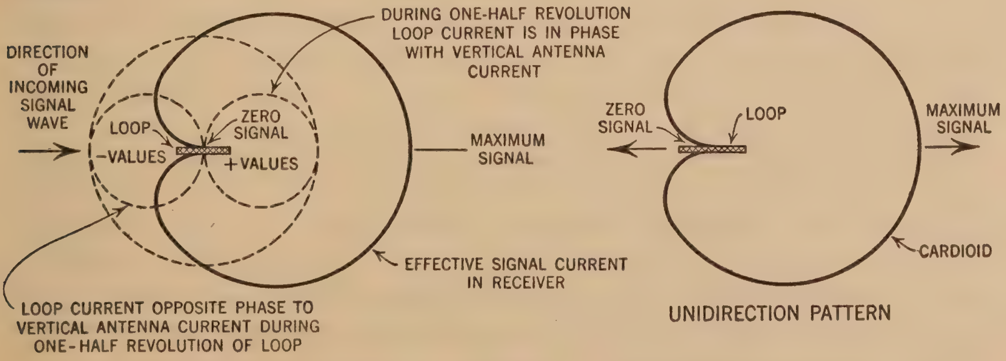
DIRECTION OF INCOMING SIGNAL WAVE
DURING ONE-HALF REVOLUTION LOOP CURRENT IS IN PHASE WITH VERTICAL ANTENNA CURRENT
LOOP
ZERO SIGNAL
−VALUES
+VALUES
MAXIMUM SIGNAL
EFFECTIVE SIGNAL CURRENT IN RECEIVER
LOOP CURRENT OPPOSITE PHASE TO VERTICAL ANTENNA CURRENT DURING ONE-HALF REVOLUTION OF LOOP
ZERO SIGNAL
LOOP
MAXIMUM SIGNAL
CARDIOID
UNIDIRECTION PATTERN

Fig. 110. The heart-shaped curve shows a unidirectional characteristic.

6.119. *Question.* What is the principal function of a vertical antenna associated with a unilateral radio direction finder?

Answer. The *sense* of direction may be definitely determined with a vertical antenna used in conjunction with a loop antenna. In other words, a vertical antenna enables the operator of a direction finder to determine the direction from which the signal is originating without the 180° ambiguity, or uncertainty, which exists when using the loop alone.

6.120. *Question.* What is the principal function of a vertical antenna associated with a bilateral radio direction finder?

Answer. The vertical antenna aids in balancing out the so-called "antenna effect" of a loop structure with respect to ground, which is done in order to obtain a more critical zero signal. This results in more accurate bearings, since the indicator is set to take readings on the minimum signal, or null point.

Discussion. A loop system which is properly balanced will give a critical zero signal as the loop is rotated about its vertical axis. Assuming proper conditions of balance, the received signal is zero when the plane of the loop is at right angles to the direction of the signal. When the plane of the loop is in the direction from which the signal is arriving the signal is maximum. The effect produced in the loop coil because of the capacity to ground of the loop structure is called "antenna effect."

6.121. *Question.* Why are loop antennas which are associated with radio direction finders metallically shielded?

Answer. Shielding improves the directive properties of a loop by minimizing the so-called "antenna effect." This effect distorts the figure-of-eight pattern, and the critical position of the loop which would give a zero signal, or null point, is no longer obtainable. With proper conditions of balance the received signal is zero when the plane of the loop is at right angles to the direction of the signal. Operation of a loop that will give the sharpest null point is to be desired since the indicator is set to take bearings on a minimum signal.

Note that the metallic shield must not be continuous entirely enclosing the loop or it would exclude the signal; the shield housing must be broken at some point with a small section of insulating material which fills in this space in order to make the loop weathertight.

6.122. *Question.* What is a "compensator" as used with radio direction finders, and what is its purpose?

Answer. A "compensator" is a mechanical device which automatically corrects errors caused by the influence of the ship's hull, rigging, and surrounding metal objects, particularly if located close to the loop. An adjustable cam or rotor movement allows the pointer showing the loop bearings either to lag or lead the actual loop position to compensate for errors observed at the time of calibration.

6.123. *Question.* How is the unilateral effect obtained in a direction finder?

Answer. The obtaining of a unilateral effect is based upon the principle that the phase of the signal current in a loop may be changed at will by swinging it to present either side toward the oncoming signal so that in a coil system of the receiver the loop signal current may be made to add to or subtract from the signal current in a vertical antenna.

How the unilateral effect is obtained. The functions during a full turn of the loop are traced out as follows: During one-half revolution of the loop the signal heard in the headphones is comparatively strong at all positions and maximum when the loop is in a plane with the direction of the sending station; this maximum signal condition indicates that a certain side of the loop is being acted upon first by the oncoming signal because this side points toward the sending station and, therefore, the loop and vertical antenna currents are *in phase.* Then during the remaining half revolution of the loop the signal becomes weaker at all loop positions until it reaches zero or minimum when the loop again is in a plane with the direction of the sending station; this zero signal condition indicates that the side of the loop which previously pointed toward the sending station is now pointing away from it, so the two currents, loop and vertical antenna currents, are in *opposite phase. Therefore when the loop is rotated a full turn the resultant signal has one broad maximum and one well-defined minimum point.* The side of the loop giving the louder signal is used in taking a unilateral bearing to indicate definitely the direction from which the signal originates. The manner in which the signal changes intensity during a complete rotation of the loop when used in conjunction with a vertical antenna is shown in Figure 109 by the cardioid, or heart-shaped curve. In other words, the cardioid is the reception pattern formed by combining a concentric circle (vertical antenna pattern) and a figure-of-eight (loop pattern). The vertical antenna is called a "sense" antenna because its use is necessary to give a unilateral effect.

6.124. *Question.* On shipboard, what factor may affect the accuracy of a direction finder after it has been properly installed, calibrated, and compensated?

Answer. Some limitations which may affect the accuracy of bearings are as follows:

(*a*) Any changes in the conditions surrounding a loop after calibration, such as changing the position of nearby metal objects, may result in an erroneous bearing.

(*b*) A signal which has traveled over intervening land in reaching a ship's station is likely to be distorted and may give a bearing which is only approximately correct.

(*c*) A signal wave which has followed a shore line for an appreciable distance may be distorted or bent and so may give an unreliable bearing.

(*d*) A signal arriving from a station a hundred miles or more away may be considered as approximately correct.

(*e*) Errors may result from bearings taken just before sunrise or just after sunset owing to so-called "night effect." A bearing cannot be relied upon if the null point shifts rapidly, thus making it appear that the sending station is suddenly changing its location. However, for distances under about 100 miles with no erratic shifting of the null point the errors due to "night effect" are usually considered negligible.

Note. All bearings are to be taken with the main antenna left "open," that is, not connected to ground, transmitter, or receiver. The antenna grounding switch is provided with auxiliary contacts which control the heater voltage supply to the direction finder receiver; these contacts close only when the switch is in the middle position and not connected either to ground or transmitter.

6.125. *Question.* What is indicated by the bearing obtained by the use of a bilateral radio direction finder?

Answer. The *line of direction* is indicated by a bilateral bearing, which means that the signal is known to originate from one of two possible directions, 180° apart.

6.126. *Question.* **What is indicated by the bearing obtained by the use of a unilateral radio direction finder?**

Answer. The *sense direction* is indicated with a unilateral bearing, which means that the direction from which the signal originates is definitely established.

6.127. *Question.* **If a vacuum tube heater burns out in an approved auto alarm, what causes the warning bells to ring?**

Answer. A relay in the heater circuit is de-energized and its contacts close a circuit to another relay which places the bells in operation. The latter relay operates independently of the circuit which normally rings the bells upon receipt of a real alarm signal. In the event of a heater burnout the bells will continue to ring if the release button is depressed.

6.128. *Question.* **What is the function of the "balancing" condenser in a direction finder?**

Answer. The balancing condenser is used to minimize "antenna effect" so that a sharper null point, or zero signal, may be obtained when swinging the loop. This enables the operator to take more accurate bearings.

6.129. *Question.* **What signal will cause an approved auto-alarm receiver to ring the warning bell?**

Answer. The receipt of a signal consisting of four consecutive dashes, each 4 seconds long with 1 second intervals within tolerance limits, will ring the bells.

Note that the auto-alarm signal consists of twelve 4-second dashes sent in 1 minute but the receipt of any four properly sent dashes in succession will actuate the selector system and ring the bells.

6.130. *Question.* **To what frequency, or band of frequencies, is an approved auto-alarm receiver tuned?**

Answer. The receiver responds to frequencies of 487.5 to 512.5 kilocycles. That is, the receiver circuits are broadly tuned to accept signals of 500 kilocycles plus or minus 12.5 kilocycles.

6.131. *Question.* **What is the maximum permissible r.m.s. value of audio voltage which can be applied to the grid of a class A audio amplifier which has a grid bias value of 10 volts?**

Answer. 7.07 volts.

Discussion. Since the grid should not be driven positive in a class A audio amplifier, for maximum audio excitation the audio *peak* amplitude will equal the bias voltage. Hence, in this example the audio *peak value* equals 10 volts and changing this to *r.m.s. value,* we have $10 \times 0.707 = 7.07$ volts.

6.132. *Question.* **What is the effect of leakage in the coupling condenser in an impedance or resistance coupled audio-frequency amplifier?**

Answer. A leaky coupling condenser would alter the bias on the amplifier and cause serious distortion.

6.133. *Question.* **What is the d-c plate voltage of a resistance coupled amplifier stage which has a plate supply voltage of 260 volts, a plate current of 1 milliampere, and a plate load resistance of 100,000 ohms?**

Answer. 160 volts.

Computation: The voltage at the plate is the difference between the supply voltage and the voltage across the load resistance. Find the voltage across the load, or $E = IR = 100{,}000 \times 0.001 = 100$ volts, and subtract this value from the d-c supply voltage, or $260 - 100 = 160$ volts.

6.134. *Question.* List four causes of distortion in a class A audio amplifier.

Answer. Distortion in a class A audio-frequency amplifier may be caused by the following: (1) Improper bias; (2) feedback, that is, regeneration in the amplifier; (3) improper load impedance; (4) overdriving the grid, that is, excessive excitation voltage.

6.135. *Question.* In a self-biased radio-frequency amplifier stage having a plate voltage of 1,250 volts, a plate current of 150 milliamperes, a grid current of 15 milliamperes, and a grid-leak resistance of 4,000 ohms, what is the value of the operating bias?

Answer. −60 volts bias.

Solution: The only values needed for working out this example are grid current and grid-leak resistance. Apply these values directly in Ohm's law to find voltage. Thus, $E = IR = 0.015 \times 4{,}000 = 60$ volts.

Note. Be sure to change milliamperes to the unit ampere before using in the formula, or 15 ma. = 0.015 ampere.

6.136. *Question.* In a radio-frequency amplifier employing fixed bias, as the plate circuit is varied in adjustment from a point below resonance to a point above resonance, what effect will be observed on the grid current?

Answer. As the plate circuit is tuned upward close to resonance the grid current will rise, at resonance it will be maximum, and for points on the other side of resonance it will again decrease.

6.137. *Question.* What is the primary function of the power-amplifier stage of a marine radiotelegraph transmitter?

Answer. To provide better frequency stability. A power-amplifier stage serves to isolate the oscillator from the antenna. Other benefits of a power-amplifier stage are that it permits the oscillator to be worked at comparatively low power with the desired output power obtained through the use of several amplifier tubes.

6.138. *Question.* In a series-fed plate circuit of a vacuum-tube amplifier, what would be the effect of a short circuit of the plate supply bypass condenser?

Answer. The plate power supply would be short-circuited, and overload protection would be depended upon to prevent any damage.

6.139. *Question.* In a shunt-fed plate circuit of a vacuum-tube amplifier, what would be the effect of an open circuit in the plate radio-frequency choke?

Answer. An open in the r-f choke would remove plate voltage from the amplifier and it would cease functioning.

6.140. *Question.* What is the function of a "dummy antenna"?

Answer. A dummy or phantom antenna is a resistive load which may be substituted for the regular antenna at the output of a transmitter to dissipate the power. Such a load is not oscillatory. The use of the dummy antenna allows the transmitter to be adjusted, tested, or perhaps warmed up prior to normal operation without radiating the carrier which would be a source of interference under such circumstances.

6.141. *Question.* What is the primary advantage to be obtained by shunting a high resistance fixed resistor across each unit of a high voltage series condenser bank in the power supply filter circuit of a transmitter?

Answer. The purpose of connecting a resistor across each condenser unit is to protect the condenser from receiving excessive voltage, which might damage it. If there is any variance in the internal resistance of condensers in a series bank the one with the higher internal resistance will have a higher voltage applied to it. Since the resistors are also in a series arrangement they form practically a voltage divider across the line which properly distributes the total voltage to keep each condenser working within its normal voltage rating.

6.142. *Question.* What is the effect of an inductance connected in series with an antenna circuit?

Answer. The resonant frequency is decreased by the addition of a series inductance, or in other terms the wavelength is increased.

6.143. *Question.* If a vacuum tube in the only radio-frequency stage of your receiver burned out, how could you make temporary repairs to permit operation of the receiver if no spare vacuum tube was available?

Answer. The antenna lead-in connection could be removed from the antenna post and reconnected to the plate lead at the defective tube's socket, thus making the primary of the r-f transformer serve as the antenna coupling coil. A blocking condenser could be used in series with the lead-in connection to keep high-voltage d.c. off the antenna and prevent possible short circuit to ground, which would short the power supply.

6.144. *Question.* What is the meaning of "high-level" modulation?

Answer. High-level modulation is modulation produced at a point in a system where the power level approximates that at the output of the system.

6.145. *Question.* What is the meaning of "low-level" modulation?

Answer. Low-level modulation is modulation produced at a point in a system where the power level is low compared with the power level at the output of the system.

6.146. *Question.* If the plate current of the final radio-frequency amplifier in a transmitter suddenly increased and radiation decreased, although the antenna circuit is in good order, what would be the possible causes?

Answer. Neutralization may have been upset in some way that would allow the amplifier to break into oscillation; interruption of r-f excitation to the amplifier; loss of grid bias.

6.147. *Question.* A master-oscillator power-amplifier type of transmitter has been operating normally. Suddenly the antenna ammeter reads zero, although all filaments are burning and plate and grid meters are indicating normal voltages and currents. What would be the possible cause(s)?

Answer. This trouble may be due to a short-circuited antenna ammeter.

6.148. *Question.* What would cause abnormally low voltage at the input power terminals of a lifeboat radiotelegraph transmitter while it is in operation?

Answer. The heavy-duty storage battery supplying power is in a discharged condition.

6.149. *Question.* What is the result of excessive coupling between the antenna and output circuits of a self-excited type of vacuum-tube transmitter?

Answer. An effect called "split tuning" results, which means that the emitted signal is likely to swing sharply from one frequency to another with consequent loss of signal at the receiving station.

6.150. *Question.* What is the purpose of the iron compound cylinders which are found in the inductances of certain marine radiotelegraph transmitters? The position of these cylinders with respect to the inductances is adjustable for what purpose?

Answer. The iron compound cylinders provide variable reactance, or permeability tuning, and a means for adjusting band width. Changes in the position of these iron cylinders vary the value of the inductance for tuning the circuits. See answers to Questions 5.78 and 6.10.

6.151. *Question.* What is the most common cause of "split tuning"?

Answer. Tight coupling between two radio-frequency circuits. The resonance curve for a condition of very close coupling has two pronounced peaks, or double humps, which indicates two frequencies differing by a relatively large percentage.

6.152. *Question.* Should the antenna circuit of a master-oscillator power-amplifier type of transmitter be adjusted to the resonant frequency before the plate tank circuit of the final stage? Give reason(s) for your answer.

Answer. No. The amplifier tube should not be operated very long with the plate tank out of resonance because the off-resonance plate current usually is fairly high even when adjustments are made on reduced power. The plate tank ordinarily should be tuned as quickly as possible and without load. Without load the plate current takes a sharp dip when the plate tank is in resonance with the excitation frequency, that is, resonance is indicated by the lowest point in the dip, or minimum plate current. The sharp dip enables a very close adjustment of plate tank resonance to be made. The antenna circuit should be adjusted after the plate tank circuit is tuned. As the antenna circuit approaches resonance, both the plate current and antenna current will rise and at resonance the antenna current will be maximum. The reaction on the plate tank due to the antenna load at resonance may slightly detune the tank; it should be retuned, which will again be indicated by minimum plate current at the dip. However, under conditions of a loaded plate tank the dip in plate current has a broad peak as compared with the sharp dip obtained when tuning the tank without load, as shown in Figure 111. The curve indicates that the minimum value of plate current at plate circuit resonance is much greater with load than without load. After these adjustments have been completed the plate voltage should be increased to give the desired power output according to the requirements.

6.153. *Question.* In a transmitter involving a master oscillator, intermediate amplifier and final amplifier, describe the order in which circuits should be adjusted in placing this transmitter in operation.

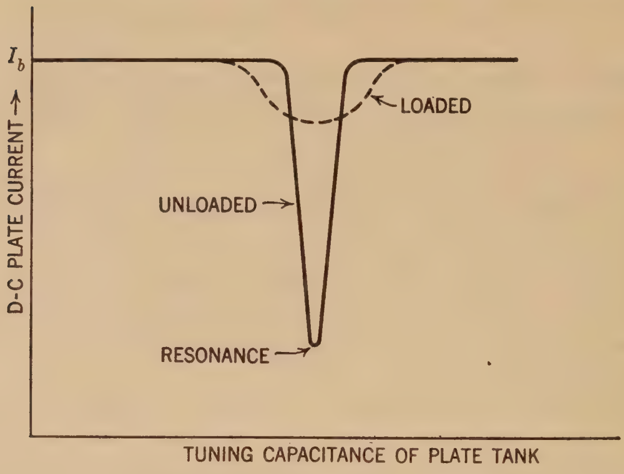

FIG. 111. The plate current dips to its lowest value at resonance.

Answer. First adjust the master oscillator without load, next the intermediate amplifier, and last the final amplifier.

6.154. *Question.* What is a "frequency doubler" stage?

Answer. A "frequency doubler" stage is an amplifier used to provide a frequency in the output which is twice the frequency of the r-f exciting voltage.

6.155. *Question.* Define "parasitic oscillations."

Answer. "Parasitic oscillations" are high-frequency currents generated in an r-f amplifier which bear no relation to the desired frequencies in the stage.

6.156. *Question.* What is the effect of parasitic oscillations?

Answer. Parasitic oscillations may cause overheating of circuit components and tube elements, a distorted output, erratic action in the r-f circuits, the radiation of spurious frequencies, and a general decrease in efficiency.

6.157. *Question.* What may cause a radio-frequency amplifier tube to have excessive plate current?

Answer. Some possible causes for excessive plate current are a soft or gassy tube, parasitic oscillations, unneutralized condition, insufficient bias, excessive plate voltage, and detuned plate circuit.

6.158. *Question.* What are some of the indications of a defective vacuum tube in a transmitter?

Answer. A soft tube, or one with a low vacuum, results in excessive plate current, or in severe cases the plate itself might overheat and show excessive color, perhaps a bright red or white heat when only a dull cherry red is permissible. A blue glow or haze seen within the envelope might result from a gassy tube. A burned-out filament obviously would give no light with voltage applied. Another possible indication would be subnormal plate current resulting from a low emission filament. Shorted tube elements would probably show internal sparking.

6.159. *Question.* At what point on a shipboard antenna system will the maximum potential be noted?

Answer. The maximum potential exists at the free end of a shipboard antenna system, that is, at the far end or ungrounded end.

6.160. ***Question.*** **What is the effect of dirty or salt-encrusted antenna insulation upon a transmitter?**

Answer. Creepage of high frequency and loss of radiated power which may affect the normal antenna ammeter reading. Losses due to corona and brush discharge are increased.

6.161. ***Question.*** **Why do many marine transmitters employ variometers rather than variable condensers as the tuning adjustments?**

Answer. The tuning units in a marine transmitter must be very rugged and able to withstand voltages greatly in excess of normal demands. Variable condensers built especially for high breakdown voltages would be large and expensive. Condensers in service are subject to arc-over from possible accumulation of dust and moisture between plates, which also affects the electrical characteristics. Besides possessing rugged qualities, a variometer has important advantages in that it allows circuit adjustments to be made over a wide frequency band and when used in an antenna system it provides loading inductance as well as a means for tuning the antenna.

6.162. ***Question.*** **What is the relationship between the antenna current and radiated power of an antenna?**

Answer. This relation is expressed by the formula $P = I^2R$, or the value of the current squared times the antenna resistance equals the radiated power.

6.163. ***Question.*** **Why is a self-excited oscillator type of transmitter undesirable for shipboard service?**

Answer. Frequency stability is poor; adjustments for obtaining the desired working power are not sufficiently independent of frequency.

6.164. ***Question.*** **What is the fundamental difference(s) between the Hartley and Colpitts oscillators?**

Answer. In the Colpitts type the oscillatory circuit is divided electrically into two capacitances, which permits one capacitance to supply grid excitation and the other to receive excitation from the plate for driving the oscillatory circuit. The Colpitts oscillator is known as the *split-capacitance* type. The Hartley oscillator is the *split-inductance* type, in which the oscillatory circuit inductance is divided electrically into two sections for similar purposes of grid and plate excitation as in the Colpitts oscillator.

6.165. ***Question.*** **How is the keying of a simple oscillator type of emergency marine transmitter usually accomplished?**

Answer. The sending key is inserted in series with the primary of the high-voltage plate transformer. (See Figure 102.)

6.166. ***Question.*** **If you found that it was impossible to keep the receiver storage "A" battery charged, and at the same time maintain the required watch period, what remedy may be found?**

Answer. Inability to keep the receiver battery properly charged under normal conditions should be corrected by changing the charging resistor to one of lower value, or by shunting another resistor of suitable value across the present one, which will increase the charging rate. However, the emergency storage battery may be used to supply the receiver for routine communication for a period of not more than 1 hour per day, in the aggregate, providing that such use does not make the battery incapable of meeting the 6-hour emergency requirements for operating the auxiliary transmitter.

6.167. *Question.* The time indications of what zone shall be used in making log entries with respect to the observance of the international silent period?

Answer. Greenwich mean time (GMT) is the time zone used for all entries in the radio station log, the time being figured according to the 24-hour system (0000 to 2359 hrs.).

Discussion. The two international silent periods of 3 minutes each begin at 15 minutes and at 45 minutes past each hour, Greenwich mean time. Each sheet of the log shall be numbered and dated and the time used for making an entry in the radio log shall be according to the 24-hour system, starting at midnight of the time at the Meridian of Greenwich. The indication GMT, indicating Greenwich mean time, shall be written at the heading of the column in which the time in four figures is entered. The time is written opposite each entry. The following gives several examples of how time is indicated according to the 24-hour system:

Local Time	*Greenwich Mean Time*
12 midnight	0000
12:45 a.m.	0045
9:00 a.m.	0900
12:00 noon	1200
3:00 p.m.	1500
11:59 p.m.	2359

6.168. *Question.* Under what circumstances must log entries be made regarding the observance of the international silent period?

Answer. During the time a watch is maintained by an operator an entry shall be made at least every 15 minutes. All calls or replies made shall be entered, giving time, stations heard or worked, and frequency involved. In general, a positive entry must be made consisting of calls heard, traffic observed, and a **specific statement as to the conduct of communication during the international silent period.** Hence, entries shall be made indicating that the watch during the silent period had been observed, incidents or communications heard, and even in the event nothing was heard this fact shall be entered.

6.169. *Question.* At what time(s) are routine transmissions forbidden in the bands of 480 to 520 kilocycles?

Answer. Routine transmissions are forbidden for 3 minutes twice an hour beginning at 15 minutes and 45 minutes past the hour, Greenwich mean time (GMT).

Note. The International Radio Regulations read: In order to increase the safety of life at sea (ships) and over the sea (aircraft), all stations in the mobile maritime service normally keeping watch on waves in the authorized bands between 365 and 515 kilocycles (822 and 583 meters) must, during their hours of service, take the necessary measures to ensure watch on the distress wave (500 kilocycles, or 600 meters) for three minutes twice an hour beginning at x h 15 and x h 45, Greenwich mean time (GMT).

6.170. *Question.* At what time(s) must the international silent period be observed?

Answer. For 3 minutes twice an hour beginning at 15 minutes and 45 minutes past the hour, Greenwich mean time (GMT). (See Question 6.169.)

6.171. *Question.* After a distress call has been transmitted, every distress traffic radiotelegram shall contain what symbol in the preamble?

Answer. In distress traffic, every radiotelegram must include the distress signal preceding the call and repeated at the beginning of the preamble.

6.172. *Question.* Under what conditions may a mobile station close if its service is not required to be continuous?

Answer. Ship stations having working hours of limited duration are governed by regulations covered in the International Radio Regulations as follows:

(1) Ship stations whose service is not continuous may not close before they have:

- (*a*) Finished all operations resulting from a distress call.
- (*b*) Exchanged so far as practicable all radiotelegrams originating in or destined for land stations situated within their range and mobile stations which, being within their range, have indicated their presence before the actual cessation of work.

(2) Any mobile station not having fixed working hours must inform the land station with which it has opened communication of the time of closing and the time of reopening its service.

(3) *a.* Any mobile station arriving in port, and whose service is, in consequence, about to close, must notify the nearest land station accordingly and, if necessary, the other land stations with which it generally communicates. It must not close until after the disposal of traffic on hand, unless the regulations of the country where it is calling do not permit this.

b. On its departure, it must notify its reopening to the land station or stations concerned from the moment when such reopening is permitted by the regulations in force in the country where the port of departure is situated.

6.173. *Question.* How long must mobile stations listen after hearing an urgent signal?

Answer. Mobile stations which hear the urgency signal must continue to listen for at least 3 minutes. At the end of this period, if no urgency message has been heard, they may resume their normal service.

6.174. *Question.* What space of time should elapse between the transmission of the international auto-alarm signal and the distress call?

Answer. When circumstances permit, the transmission of the distress call is separated from the end of the alarm signal by an interval of 2 minutes' silence.

6.175. *Question.* What exceptions are permitted to the regulation which states that a mobile station which has no fixed working hours must advise the land station with which it is in communication of the closing and reopening hours?

Answer. The exceptions are:

(1) Any mobile station must not *close* until after the disposal of traffic on hand, unless the regulations of the country where it is calling do not permit this.

(2) On its departure, any mobile station must notify its *reopening* to the land

station or stations concerned from the moment when such reopening is permitted by the regulations in force in the country where the port of departure is situated.

6.176. *Question.* **How frequently must an entry be made in the marine radio log while a radio watch is being maintained?**

Answer. During the time a watch is maintained by an operator, an entry shall be made at least every 15 minutes.

6.177. *Question.* **During what periods must a distress message be repeated following the initial transmission?**

Answer. The distress message must be repeated at intervals until an answer is received, and especially during the silence periods. The intervals must, however, be long enough to allow stations preparing to reply to start their sending apparatus.

6.178. *Question.* **Upon what bodies of water is the frequency of 500 kilocycles not utilized as the international calling and distress frequency?**

Answer. The frequency of 500 kilocycles is utilized as the international calling and distress frequency on all bodies of water.

Note. The regulations have been changed which formerly made the Great Lakes the exception to the rule. For many years 410 kilocycles was the calling and distress frequency. It is now 500 kilocycles, the same as for the oceans and all other bodies of water.

6.179. *Question.* **What stations shall be in control of distress traffic?**

Answer. The control of the distress traffic rests with the mobile station in distress or with the mobile station which sends the distress call in the event the station in distress is not itself in a position to transmit it. These stations may delegate the control of the distress traffic to another station.

6.180. *Question.* **What transmission should precede the transmission of the distress call?**

Answer. When circumstances permit the *alarm signal* should precede the distress call.

6.181. *Question.* **Describe how a distress call should be made.**

Answer. The distress call comprises (1) the distress signal sent three times, (2) the word DE, and (3) the call sign of the mobile station in distress, sent three times.

6.182. *Question.* **Under what circumstances and by whom may the international auto-alarm signal be transmitted to announce an urgent cyclone warning?**

Answer. The alarm signal may be used for this purpose only by coast stations duly authorized by their government.

6.183. *Question.* **While a vessel is at sea, how frequently must the auto alarm be tested?**

Answer. The auto alarm must be tested at least once every 24 hours while a vessel is at sea. The test button on the alarm panel is used for this purpose and the timing of the dashes and spaces is made by reference to the sweep seconds hand of the radio station clock. Bridge bell and warning light and operator's room bell must show correct operation when this test is made. A statement that the foregoing has been fulfilled must be entered daily in the radio station log.

6.184. *Question.* Describe the number of dashes, or dots, and spaces which compose the international auto-alarm signal and indicate the time intervals involved.

Answer. The alarm signal is composed of a series of 12 dashes transmitted in 1 minute, the duration of each dash being 4 seconds and the duration of the interval between two dashes, 1 second.

Tolerances: The alarm signal will actuate the auto-alarm selector system provided the dashes have a duration of not less than 3½ seconds, or more than 4½ seconds and provided the intervals between dashes are not less than 1⁄10 second or more than 1½ seconds. Auto alarms for vessels of the U. S. Registry must require 4 consecutive dashes to actuate the alarms.

Automatic-alarm signal. The section of the International Radio Regulations covering the alarm signal includes the following: The alarm signal may be sent by hand or by an automatic apparatus. Any ship station working in the band 365-515 kilocycles (822-583 meters) not equipped with automatic apparatus for the emission of the automatic alarm signal must be permanently equipped with a clock clearly indicating seconds, preferably by means of a moving hand making 1 revolution per minute. This clock must be placed so as to be clearly visible from the operating table, in order that the operator may, by keeping it in view, easily and correctly time the different elements of the alarm signal.

6.185. *Question.* Describe the "safety" signal.

Answer. The "safety" signal is used in radiotelegraphy and radiotelephony as follows:

Radiotelegraphy. In radiotelegraphy the safety signal consists of three repetitions of the group TTT sent with the letters of each group and the successive groups clearly separated from each other. This signal is followed by the word DE and by the call sign of the station which emits it, sent three times. It indicates that the station is about to transmit a message concerning the safety of navigation or giving important meteorological warnings.

Radiotelephony. In radiotelephony, the word SECURITY (corresponding to the French pronunciation of the word sécurité) repeated three times is used as the safety signal.

6.186. *Question.* During what periods must the safety signal be transmitted?

Answer. In the maritime mobile service, apart from the messages of which the transmission is made at fixed times, *the safety signal must be transmitted toward the end of the first silence period which occurs* and the message is transmitted immediately after the silence period.

6.187. *Question.* Indicate the order of priority of the various types of radio communications.

Answer. The order of priority of radio communications in the mobile service is as follows:

1. Distress calls, distress messages, and distress traffic.
2. Communications preceded by an urgency signal.
3. Communications preceded by the safety signal.
4. Communications relative to direction-finding bearings.

5. Government radiotelegrams for which the right of priority has not been waived.
6. All other communications.

6.188. ***Question.*** **Upon hearing a safety signal, what should the operator at the receiving station do?**

Answer. All stations hearing the safety signal must continue to listen on the wave on which the safety signal has been transmitted until the message announced by it is ended; they must also remain silent on all waves capable of interfering with the message.

6.189. ***Question.*** **When the auto-alarm bell rings, what should the operator do?**

Answer. The bells may sound for one of three reasons, namely: (1) True alarm signal has been received; (2) false alarm from a combination of interference and regular code signals, a remote possibility; (3) false alarm due to improper operation or equipment failure. The three possibilities are discussed below regarding what the operator should do upon hearing the alarm bell ring.

(1) The operator should proceed immediately to the radio room and depress the reset button, or release key, located on the auto-alarm panel. If this stops the ringing of the bells the operator should quickly plug his headphones in the phone jack provided for monitoring and listen for any signals or messages that would indicate that a true alarm signal had been received. If a true alarm has been received the operator should at once begin a manual watch. The alarm signal should be followed within 2 minutes by either an urgent cyclone warning or a distress call and distress message from a vessel in need of assistance. The full text of the distress traffic heard or worked and the time the operator entered the radio room should be inserted in the radio station log.

(2) If a false alarm sounded the bells, as determined by subsequent listening on the 500 kilocycle band, an appropriate entry of this incident should be made in the log.

(3) If the bells continue to ring after the reset button, or release key, is depressed this indicates faulty operation. The operator should proceed to correct the trouble. Log entries should be made which include a statement giving particulars as to the time the repairs or adjustments were made necessary; cause of the failure; parts removed, added, or substituted, or repairs needed; the time the alarm was restored to normal operating condition.

6.190. ***Question.*** **If you received a distress call signed by a call signal composed of five letters, could you determine the type of craft which transmitted the signal?**

Answer. Call signals consisting of five letters are assigned to *aircraft* stations.

6.191. ***Question.*** **You intercept "CQ CQ WVS TFC QSY 735 AS." What does this mean?**

Answer. This communication has the following meaning:

> "A general call (CQ) is sent to all mobile stations within the range of a coastal station (WVS in this case). The coastal station will follow this communication with a traffic list (TFC), giving the call signs of mobile stations for which it has traffic on hand. The coastal station will shift (QSY) from the calling wave on which this communication is sent to the

working wave (735 meters) it will use for the transmission of the traffic list and on which the mobile stations will reply. A short waiting period (AS) now follows which allows all stations concerned to shift from the calling to the working wave."

The abbreviations have the following meanings:
CQ is a general call "to all stations."
WVS is the call letter of a coastal station.
TFC stands for "traffic."
QSY stands for "shift to transmission on .... kilocycles (or meters)."
735 is the wavelength in meters.
AS stands for "waiting period" to allow sufficient time in which to shift from calling wave to working wave (735 meters in this case).

Notation concerning the traffic list. The International Radio Regulations state that coast stations must, so far as practicable, transmit their calls in the form of "traffic lists" consisting of the call signs of all mobile stations for which they have traffic on hand and which are within their range of action. The coast stations add, after their own call sign, service abbreviations indicating the working wave which they wish to use for transmission. Mobile stations which hear their call sign during this transmission must reply as soon as they can do so, following so far as possible the order in which they were called.

6.192. *Question.* Upon hearing an SOS, what should an operator do?

Answer. All stations which hear it must immediately cease any transmission capable of interfering with the distress traffic and must listen on the wave used for the emission of the distress call.

6.193. *Question.* On a vessel of the United States, equipped with an approved auto alarm, where is the control button located which silences the warning bells?

Answer. The reset control button is located on the panel of the auto alarm located in the radio room. The three alarm bells necessary with this equipment are located one in the radio room, one on the bridge, and one in the radio operator's quarters. After the bells start ringing they can be stopped only by going to the radio room and depressing the reset control button.

6.194. *Question.* What is the radiotelegraph "urgent" signal?

Answer. In radiotelegraphy, the urgency signal consists of three repetitions of the group XXX, sent with the letters of each group and the successive groups clearly separated from each other; it is sent before the call.

6.195. *Question.* With what type(s) of emission and upon what frequency should a transmitter be adjusted to transmit a distress call?

Answer. In case of distress, the wave to be used is the international distress wave, that is, 500 kilocycles (600 meters) and the emission used must be preferably type A2 or B. Ships which cannot transmit on the international distress wave use their normal calling wave.

6.196. *Question.* Upon what band of radio frequencies must an approved auto-alarm receiver function?

Answer. The receiver responds to frequencies of 487.5 to 512.5 kilocycles. That is, the receiver is broadly tuned to accept signals of 500 kilocycles plus or minus 12.5 kilocycles.

6.197. ***Question.*** **Upon compulsorily equipped vessels which are required to have an accurate clock in the radio room, how frequently must this clock be adjusted and compared with standard time?**

Answer. The clock must be checked at least once every 24 hours.

6.198. ***Question.*** **Within what frequency band limits do all United States marine radiobeacon stations operate?**

Answer. From 285 to 315 kilocycles (1,053 to 952 meters).

6.199. ***Question.*** **Upon what frequency should a navy direction-finding station be called to obtain a radio bearing?**

Answer. The normal wave for direction-finding in the maritime services is the wave of 375 kilocycles (800 meters).

6.200. ***Question.*** **Upon what band, in addition to the 350-515 kilocycle band, must a main receiver on a compulsorily equipped United States ship be capable of operation? What is the purpose of this additional band?**

Answer. In the band from 100 to 160 kilocycles (3,000 to 1,875 meters). A large amount of traffic is handled on the long-wave band, and all marine receivers must be capable of reception on this band. The transmission of waves of type A1 only are authorized in the long-wave band.

6.201. ***Question.*** **While a vessel is in port, how frequently should the emergency equipment be tested?**

Answer. Tests are not required while a vessel is in port, except when preparing to leave port.

6.202. ***Question.*** **How frequently must the quantity of fuel in the supply tank for use with an oil- or gas-driven emergency generator be checked while the vessel is in the open sea?**

Answer. A daily check on the fuel supply shall be made and the results entered daily in the log. During stormy weather when such tests might be impracticable or dangerous they may be postponed with proper notation of the fact entered in the log.

6.203. ***Question.*** **While the vessel is in the open sea, how frequently must the specific gravity of the emergency battery be taken?**

Answer. Once daily.

6.204. ***Question.*** **While the vessel is in the open sea, how frequently must the emergency equipment be tested?**

Answer. Once daily.

6.205. ***Question.*** **What is the principal port of the United States, on the Pacific Coast, at which navigation lines terminate?**

Answer. San Francisco.

6.206. ***Question.*** **In what city is the major telecommunication center of the United States located?**

Answer. New York City.

6.207. ***Question.*** **What is the approximate latitude of Colon, Republic of Panama?**

Answer. Approximately 9°N.

6.208. ***Question.*** **In what ocean is the island of Guam located?**

Answer. Pacific Ocean.

6.209. *Question.* To what continent do the greatest number of telecommunication channels from the United States extend?

Answer. Europe.

6.210. *Question.* What is the principal Atlantic Coast port of the United States at which navigation lines terminate?

Answer. New York City.

6.211. *Question.* List four principles by which an e.m.f. may be generated by sound waves?

Answer. Dynamic; static; thermal; chemical.

6.212. *Question.* What is indicated in a radiotelephone transmitter by an increase in antenna current without carrier shift?

Answer. The modulating audio wave is normal and symmetrical and the output of the amplifier is linear.

6.213. *Question.* What methods may be used to reduce "fringe howl" in a regenerative receiver?

Answer. A resistor of high value may be connected across the primary of the first a-f transformer at the detector output to reduce the plate load impedance. The value of the resistor when connected across the primary terminals should be equal approximately to the plate resistance of the tube. In some cases a lower resistance grid leak might remedy this condition. Fringe howl is due to the regenerative feedback being just sufficient to maintain oscillations and with such critical operation the time constant of the leak and condenser may result in the interruption of oscillations to cause a sustained sound, or the plate load impedance may be too high and feeding back energy in proper phase to support the oscillations.

6.214. *Question.* Knowing the intermediate frequency and the signal frequency to which a superheterodyne receiver is tuned, how would you determine the most probable frequency on which "image" reception would occur?

Answer. The image frequency equals the sum of the signal frequency and twice the value of the intermediate frequency.

6.215. *Question.* How is the degree of coupling varied in a pi network used to transfer energy from a vacuum tube plate circuit to an antenna?

Answer. The coupling is adjusted by varying the output condenser in series with the line feeding the antenna. An example of a pi network in which the two condensers, C1 and C2, are varied simultaneously to adjust coupling is shown in Figure 112.

6.216. *Question.* What means are usually provided to prevent the operation of the ship's transmitter when the auto-alarm is in use?

Answer. The key circuit of the ship's transmitter is opened by contacts on the auto-alarm antenna switch when placed in the operating position.

6.217. *Question.* Explain how you would determine the value of cathode-bias resistor for a specific amplifier stage.

Answer. Since the voltage across the bias resistor will be the grid bias, we need to know the amount of current which will flow through this resistor and its resistance value. For a triode the current is the plate current and for a tetrode

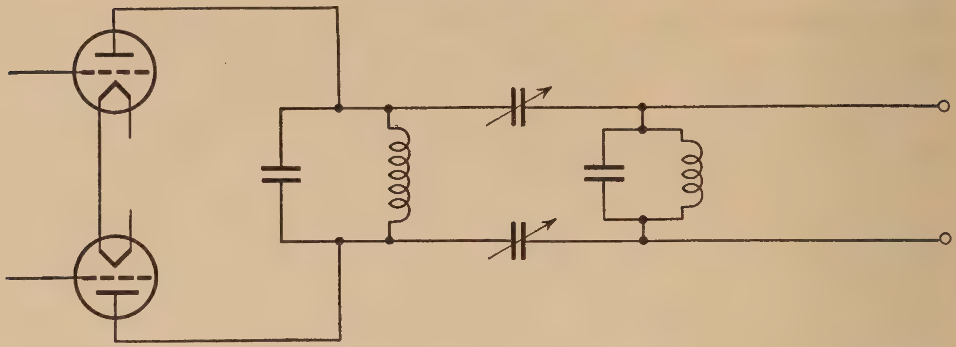

FIG. 112. Example of variable condensers used to vary the degree of coupling in a pi network.

both plate and screen-grid currents. Ohm's law is used to find the value of the bias resistance for a tube operating as a linear amplifier as follows:

$R_c = \frac{E_c}{I_{bo}}$, where E_c = d-c voltage desired on grid (in volts),
I_{bo} = total d-c emission current in amperes (for a triode this is the plate current),
R_c = cathode bias resistor (in ohms).

6.218. *Question.* **In a class A audio-frequency amplifier, what is the main advantage obtained through the use of two triodes in push-pull as compared with parallel operation?**

Answer. Distortion due to the second harmonic component is effectively balanced out in a push-pull stage. Other advantages of push-pull over parallel operation are: greater undistorted power output; reduced hum ripple with equivalent filter systems; prevention of core saturation of the output transformer; equalization of the output of each tube when excitation is applied.

6.219. *Question.* **Explain briefly the construction and characteristics of a beam power tube.**

Answer. In a beam power tube the spirally wound turns comprising the control grid and the screen grid are placed directly in line with each other. This construction permits beams of electrons in flowing from cathode to plate to pass straight through the open meshes between the turns so that practically no electrons go to the screen. One type of beam power tube does not use an actual suppressor grid but instead beam-forming plates operated at cathode potential, which prevent stray secondary electrons from the plate from getting to the screen outside of the beam. This type of tube draws very little screen grid current owing to the especially effective suppressor action. The advantages resulting from the alignment of the grids and other features are high power output, high power sensitivity, and high efficiency.

6.220. *Question.* **Explain the operating procedure employed in neutralizing a radio-frequency power amplifier, using a thermocouple ammeter as an indicating device.**

Answer. It will be necessary to remove all power and connect the thermocouple ammeter in series with the plate tank circuit, preferably in the low potential side. Before touching any wiring, however, the usual precautions should be observed with regard to discharging any high-voltage condensers that may hold a charge. Then remove the plate voltage from the amplifier but keep the plate radio-frequency circuit intact. Now operate the amplifier normally with excitation applied and with proper filament voltage but without plate voltage. Proceed to tune the plate tank to resonance as indicated by maximum reading on the thermocouple ammeter. Follow this by adjusting the neutralizing condenser for a minimum indication on this ammeter. These adjustments may have the effect of slightly detuning the driver plate tank, which should be retuned to resonance as indicated by minimum plate-current dip in the driver stage. Since one adjustment affects another, the amplifier plate tank again should be returned to resonance as shown by maximum indication on the ammeter. However, this maximum normally is much less than the previous maximum because with each readjustment the amplifier should approach the neutralized condition, as shown by a gradual decrease of r.f. in its plate tank circuit. Again the neutralizing condenser is adjusted to give the lowest r-f indication or, if possible, zero indication. After repeating the foregoing steps several times, a setting for the neutralizing condenser is usually found which shows no reading on the thermocouple ammeter; the amplifier then would be properly neutralized. The final steps are to remove the thermocouple ammeter, reconnect the plate tank circuit, apply plate voltage, and tune the tank for minimum plate-current dip.

6.221. *Question.* For what purposes are decoupling networks used in audio-frequency amplifiers?

Answer. The purposes of decoupling networks are to prevent regenerative coupling and oscillation between the stages due to the common impedance of the plate power supply. The frequency of such oscillation, when permitted, is usually very low and is called "motor-boating."

6.222. *Question.* Under what circumstances is a station in the mobile service not required to listen to distress traffic?

Answer. A station of the mobile service which, while following distress traffic of which it has knowledge, if able to continue its normal service may do so when the distress traffic is well established, on the following conditions:

(*a*) The use of the distress wave, 500 kilocycles (600 meters), on which the distress traffic is taking place and the use of type B waves are forbidden.

(*b*) The use of type A1 waves, with the exception of those which might disturb the distress traffic, is permitted.

6.223. *Question.* What interval of time must elapse between the end of the auto-alarm signal and an urgent cyclone warning?

Answer. In the case of urgent cyclone warnings, the emission of the warning must not begin until 2 minutes after the termination of the alarm signal.

6.224. *Question.* Describe the international auto-alarm signal.

Answer. The alarm signal is composed of a series of 12 dashes transmitted in 1 minute, the duration of each dash being 4 seconds and the duration of the interval between two dashes, 1 second. (See Question 6.184.)

6.225. *Question.* What is the international distress frequency for stations in the mobile service?

Answer. 500 kilocycles.

APPENDIX I*

PART 13.—RULES GOVERNING COMMERCIAL RADIO OPERATORS

GENERAL

13.1 Licensed operators required.[1]—Unless otherwise specified by the Commission, the actual operation of any radio station for which a station license is required shall be carried on only by a licensed radio operator of the required class.[2]

13.2 Classes of licenses.—The classes of commercial operator licenses issued by the Commission are:

(*a*) Commercial radiotelephone group:

(1) Radiotelephone second-class operator license.
(2) Radiotelephone first-class operator license.

(*b*) Commercial radiotelegraph group:

(1) Radiotelegraph second-class operator license.
(2) Radiotelegraph first-class operator license.

(*c*) Restricted commercial group:

(1) Restricted radiotelephone operator permit.
(2) Restricted radiotelegraph operator permit.

13.3 Dual holding of licenses.—A person may not hold more than one radiotelegraph operator license (or restricted radiotelegraph permit) and one radiotelephone operator license (or restricted radiotelephone operator permit) at the same time.

13.4 Term of licenses.—Commercial operator licenses are normally issued for a term of 5 years from the date of issuance.

APPLICATIONS

13.11 Procedure.—The application form in duplicate for operator license, properly completed and signed, shall be submitted in person or by mail to the office at which the applicant desires to be examined, which office will make the final arrangements for conducting the examination. If the application is for renewal of license,[3] it must be submitted during the last year of the license term and if the service requirements are fulfilled[4] the renewal license may be issued by mail. A renewal application shall also be accompanied by the license to be renewed.

13.12[5] **Special provisions, radiotelegraph first class.**—An applicant for the radiotelegraph first-class operator license must be at least 21 years of age at the time the license is issued and shall have had an aggregate of 1 year of satisfactory service as a radiotelegraph operator manipulating the key of a manually operated radiotelegraph station on board a ship or in a manually operated coastal telegraph station.

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* Reprinted from part 13 of the F.C.C. Rules and Regulations.

[1] Wherever the term "license" is used generally to denote an authorization from the Commission, it includes both "license" and "permit."

[2] See section 13.61.

[3] All outstanding radiotelegraph licenses bearing an endorsement granting privileges comparable with a radiotelephone license of any class shall be considered as two separate licenses and application for renewal thereof shall be made separately.

[4] See section 13.28.

[5] Radiotelegraph first-class licenses now held by persons under 21 years of age may be renewed without regard to the age limit provided by section 13.12.

EXAMINATIONS

13.21 Examination elements.—Written examinations will comprise questions from one or more of the following examination elements:

(1) *Basic law.*—Provisions of law and regulation with which every operator should be familiar.

(2) *Basic theory and practice.*—Technical matters appropriate for every class of license except restricted radiotelephone operator permit.

(3) *Radiotelephone.*—Additional matters, both legal and technical, including radiotelephone theory and practice.

(4) *Advanced radiotelephone.*—Theory and practice applicable to broadcast station operation.

(5) *Radiotelegraph.*—Additional matters, both legal and technical, including radiotelegraph theory and practice.

(6) *Advanced radiotelegraph.*—Radiotelegraph theory and practice of wider scope, particularly with respect to ship radio matters (direction finders, ship radiotelephone stations, spark transmitters, etc.).

13.22 Examination requirements.—Applicants for original licenses will be required to pass examinations as follows:

(*a*) Radiotelephone second-class operator license:

(1) Ability to transmit and receive spoken messages in English.
(2) Written examination elements: 1, 2, and 3.

(*b*) Radiotelephone first-class operator license:

(1) Ability to transmit and receive spoken messages in English.
(2) Written examination elements: 1, 2, 3, and 4.

(*c*) Radiotelegraph second-class operator license:

(1) Ability to transmit and receive spoken messages in English.
(2) Transmitting and receiving code test of sixteen (16) code groups per minute.
(3) Written examination elements: 1, 2, 5, and 6.

(*d*) Radiotelegraph first-class operator license:

(1) Ability to transmit and receive spoken messages in English.
(2) Transmitting and receiving code test of twenty-five (25) words per minute plain language and twenty (20) code groups per minute.
(3) Written examination elements: 1, 2, 5, and 6.

(*e*) Restricted radiotelephone operator permit:

(1) Ability to transmit and receive spoken messages in English.
(2) Written examination element: 1.

(*f*) Restricted radiotelegraph operator permit:

(1) Transmitting and receiving code text of sixteen (16) code groups per minute.
(2) Written examination elements: 1, 2, and 5.

13.23 Form of writing.—Written examinations shall be in English and shall be written by the applicant in longhand in ink, except that diagrams may be in pencil.

13.24 Passing mark.—A passing mark of 75 percent of a possible 100 percent will be required on each element of a written examination.

13.25 **New class, additional requirements.**—The holder of a license, who applies for another class of license, will be required to pass only the added examination elements for the new class of license.

13.26 **Canceling and issuing new licenses.**—If the holder of a license qualifies for a higher class in the same group, the license held will be canceled upon the issuance of the new license. Similarly, if the holder of a restricted operator permit qualifies for a first- or second-class operator license of the corresponding type, the permit held will be canceled upon issuance of the new license.

13.27 **Eligibility for reexamination.**—An applicant who fails an examination element will be ineligible for 2 months[6] to take an examination for any class of license requiring that element. Examination elements will be graded in the order listed,[7] and an applicant may, without further application, be issued the class of license for which he qualifies.

13.28 **Renewal examinations and exceptions.**[8]—A license may be renewed without examination provided the service record on the license[9] shows at least 3 years' satisfactory service in the aggregate during the license term and while actually employed as a radio operator under that license; or shows at least 2 years' service in the aggregate, under the same conditions, of which 1 year must have been continuous and immediately prior to the date of application for renewal.

If the above requirements have not been fulfilled, but the service record shows at least 3 months' satisfactory service in the aggregate, while actually employed as a radio operator under the license during the last 3 years of the license term, a license may be renewed upon the successful completion of a renewal examination which may be taken at any time during the last year of the license term.

Renewal examinations will consist of the same elements as for original licenses. However, the written examination will be directed toward a determination of the applicant's qualifications to continue to hold the license for which he has previously qualified. If the renewal examination is not successfully completed before expiration of the license sought to be renewed, or if the service is not acceptable, the applicant will be examined as for the original license.

CODE TESTS

13.41 **Transmitting speed requirements.**—An applicant is required to transmit correctly in the International Morse Code for 1 minute at the rate of speed prescribed in these rules for the class of license desired.

13.42 **Transmitting test procedure.**—Transmitting tests shall be performed by the use of the conventional Morse key except that a semi-automatic key, if furnished by the applicant, may be used in transmitting code tests of 25 words per minute.

13.43 **Receiving speed requirements.**—An applicant is required to receive the International Morse Code by ear, and legibly transcribe, consecutive words or code groups for a period of 1 minute without error at the rate of speed specified in the rules for the class of license for which application is made.

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[6] A month after date is the same day of the following month, or if there is no such day, the last day of such month. This principle applies for other periods. For example, in the case of the 2-month period to which this note refers, an applicant examined December 1 may be reexamined February 1, and an applicant examined December 29, 30, or 31 may be reexamined the last day of February, while one examined February 28 may be reexamined April 28.

[7] See Section 13.28.

[8] Paragraph (2) of rule 439 shall remain in effect with respect to renewals of 3-year licenses outstanding on July 1, 1939.

"Rule 439 (2) All operator licenses, except amateur, may be renewed without examination, provided—

(*a*) The applicant has had 90 days' satisfactory service during the 6-month period prior to the date the application for renewal of license is due to be filed, namely, 60 days prior to the expiration date, or

(*b*) The applicant has had at least 12 months' satisfactory service during the license term prior to the date the application for renewal of license is due to be filed."

[9] See sections 13.91 to 13.94, inclusive.

13.44 **Receiving test procedure.**—Receiving code tests shall be written in longhand either in ink or pencil except that in the case of the 25 words per minute code test, a typewriter may be used when furnished by the applicant.

13.45 **Computing word or code groups.**—Each five characters shall be counted as one word or code group. Punctuation marks or figures count as two characters.

SCOPE OF AUTHORITY

13.61 **Operators' authority.**—The various classes of commercial operator licenses issued by the Commission authorize the holders thereof to operate radio stations, except amateur, as follows:

(*a*) *Radiotelephone second-class operator license.*—Any station while using type A–0, A–3, A–4, or A–5 emission except standard broadcast stations, International Broadcast stations, or ship stations licensed to use power in excess of 100 watts and type A–3 emission for communication with coastal telephone stations.

(*b*) *Radiotelephone first-class operator license.*—Any station while using type A–0, A–3, A–4, or A–5 emission except ship stations licensed to use a power in excess of 100 watts and type A–3 emission for communication with coastal telephone stations.

(*c*) *Radiotelegraph second-class operator license.*—Any station while using type B, A–0, A–1, A–2, A–3, or A–4 emission except—

(1) Any of the various classes of broadcast stations other than a relay broadcast station, or

(2) On a passenger[10] vessel required by treaty or statue to maintain a continuous radio watch by operators or on a vessel having continuous hours of service for public correspondence, the holder of this class of license may not act as chief operator.

(3) On a *vessel* (other than a vessel operated exclusively on the Great Lakes) required by treaty or statute to be *equipped* with a *radiotelegraph* installation, the holder of this class license may not act as chief or sole operator until he has had at least 6 months' satisfactory service as a qualified radiotelegraph operator on a vessel of the United States.

(*d*) *Radiotelegraph first-class operator license.*—Any station while using type B, A–0, A–1, A–2, A–3, or A–4 emission except—

(1) Any of the various classes of broadcast stations other than a relay broadcast station.

(2) On a *cargo vessel* (other than a vessel operated exclusively on the Great Lakes) required by treaty or statute to be *equipped* with a *radiotelegraph* installation, the holder of this class license may not act as chief or sole operator until he has had at least 6 months' satisfactory service as a qualified radiotelegraph operator on a vessel of the United States.

(*e*) *Restricted radiotelephone operator permit.*—Any station while using type A–0, A–3, or A–4 emission: *Provided,* That—

(1) Such operator is prohibited from making adjustments that may result in improper transmitter operation.

(2) The equipment is so designed that none of the operations necessary to be performed during the course of normal rendition of service may cause off-frequency operation or result in any unauthorized radiation.

(3) Any needed adjustments of the transmitter that may affect the proper operation of the station are regularly made by or in the presence of an operator holding a first or second class license, either telephone or telegraph, who shall be responsible for the proper operation of the equipment.

Exceptions:

(1) The permit is not valid for the operation of any of the various classes of broadcast stations other than a relay broadcast station.

(2) The permit is not valid for the operation of a coastal telephone station or a coastal harbor station other than in the Territory of Alaska.

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[10] A ship shall be considered a passenger ship if it carries or is licensed or certificated to carry more than 12 passengers. A cargo ship means any ship not a passenger ship.

(3) The permit is not valid for the operation of a ship station licensed to use type A–3 emission for communication with coastal telephone stations.

(*f*) *Restricted radiotelegraph operator permit.*—Any station while using type B, A–0, A–1, A–2, A–3, or A–4 emission: *Provided,* That, in the case of equipment designed for and using type A–3 or A–4 emission—

(1) Such operator is prohibited from making adjustments that may result in improper transmitter operation.

(2) The equipment is so designed that none of the operations necessary to be performed during the course of normal rendition of service may cause off-frequency operation or result in any unauthorized radiation.

(3) Any needed adjustments of the transmitter which may affect proper operation of the station are regularly made by or in the presence of an operator holding a first or second class license, either telephone or telegraph, who shall be responsible for the proper operation of the equipment.

Exceptions:

(1) The permit is not valid for the operation of any of the various classes of broadcast stations other than a relay broadcast station.

(2) The permit is not valid for the operation of a ship station licensed to use type A–3 emission for communication with coastal telephone stations.

(3) The license is not valid for the operation of a radiotelegraph station on board a vessel required by treaty or statute to be equipped with a radio installation.

(4) The license is not valid for the operation of any ship telegraph, coastal telegraph, or marine-relay station open to public correspondence.

13.62 Special privileges.—(*a*) Any operator may operate any station in the experimental service, while using frequencies above 300,000 kilocycles.

(*b*) Subject to the limitations set forth herein,[11] the holder of any class radiotelephone operator license may operate a radiotelephone point-to-point station, a coastal harbor, or coastal telephone station while using A–1 or A–2 emission, for testing or other transmission entirely secondary and incidental to the service of such station.

13.63 Operator's responsibility.—The licensed operator responsible for the maintenance of a transmitter may permit other persons to adjust a transmitter in his presence for the purpose of carrying out tests or making adjustments requiring specialized knowledge or skill, provided that he shall not be relieved thereby from responsibility for the proper operation of the equipment.

MISCELLANEOUS

13.71 Issue of duplicate license.—An operator whose license or permit has been lost, mutilated, or destroyed, shall immediately notify the Commission. A sworn application for duplicate should be submitted to the office of issue embodying a statement attesting to the facts thereof. If a license has been lost, the applicant must state that reasonable search has been made for it, and further, that in the event it be found either the original or the duplicate will be returned for cancellation. The applicant must also give a statement of the service that has been obtained under the lost license.

13.72 Exhibiting signed copy of application.—When a duplicate operator license or permit has been requested, or request for renewal upon service has been made, the operator shall exhibit in lieu thereof a signed copy of the application for duplicate, or renewal, which has been submitted by him.

13.73 Supervision of examinations for permit.—Persons other than employees of the Commission may be authorized to supervise examinations for Restricted Radiotelephone Operator Permits for one or more employees of a division of local or State Government: *Provided*—

(*a*) That the absence of such employees for the purpose of taking an examination at a field office or designated examining city would interfere with the proper functioning of the division, and

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[11] Section 13.61.

(*b*) That the chief of police, director of public safety, or other officials of equal responsibility furnish the names of the persons to be examined and designate an official by name and title to supervise the examination. The application for supervisory examination shall be made to the inspector in charge of the district in which the applicants are located.

13.74 Verification card.—The holder of an operator license who operates any station in which the posting of an operator license is not required, may, upon filing application[12] in duplicate, accompanied by his license, obtain a Verification Card.[13] This card may be carried on the person of the operator in lieu of the original operator license: *Provided,* The license is readily accessible within a reasonable time for inspection upon demand by an authorized Government representative.

13.75 Posting license or verified statement.—The holder of a radiotelegraph or radiotelephone first or second class license who is employed as a service and maintenance operator at stations operated by holders of Restricted Operator Permits shall post at such station his operator license or a verified statement from the Commission[14] in lieu thereof.

SERVICE

13.91 Endorsement of service record.—A station licensee, or his duly authorized agent, or the master of a vessel acting as the agent of a licensee, shall endorse the service record appearing on said operator license, showing the call letters and types of emission of the station operated, the nature and period of employment, and quality of performance of duty.

13.92 Aviation service endorsement.—If the operator has operated more than three stations in the aviation service, the service may be shown by giving the name of the aviation chain or company in lieu of listing the call letters of the several stations.

13.93 Service acceptability.—Credit will be allowed only for satisfactory service obtained under conditions that required the employment of licensed operators, or when obtained at United States Government stations.

13.94 Statement in lieu of service endorsement.—The holder of a radiotelegraph license or a restricted radiotelegraph operator permit desiring an endorsement to be placed thereon attesting to an aggregate of at least 6 months' satisfactory service as a qualified operator on a vessel of the United States, may, in the event documentary evidence cannot be produced, submit to any office of the Commission a statement under oath accompanied by the license to be endorsed, embodying the following:

(*a*) Names of ships at which employed;
(*b*) Call letters of stations;
(*c*) Types of emission used:
(*d*) Type of service performed as follows:

    (1) Manual radiotelegraph operation only; and
    (2) Transmitter control only; or
    (3) Combination of (1) and (2) running concurrently;

(*e*) Whether service was satisfactory or unsatisfactory;
(*f*) Period of employment;
(*g*) Name of master, employer, licensee, or his duly authorized agent.

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[12] Form 756.

[13] Form 758–F.

[14] Form 759.

APPENDIX II

EXTRACTS FROM RADIO LAWS

1. Communications Act of 1934, As Amended.
2. International Radiotelegraph Conference, Madrid 1932.
3. International Radio Regulations (Cairo Revision, 1938).
4. Rules and Regulations, Federal Communications Commission.

(1) Extracts of the Communications Act of 1934, As Amended

SECTION 1. For the purpose of regulating interstate and foreign commerce in communication by wire and radio so as to make available, so far as possible, to all the people of the United States a rapid, efficient, Nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges, for the purpose of the national defense, for the purpose of promoting safety of life and property through the use of wire and radio communication, and for the purpose of securing a more effective execution of this policy by centralizing authority heretofore granted by law to several agencies and by granting additional authority with respect to interstate and foreign commerce in wire and radio communication, there is hereby created a Commission to be known as the "Federal Communications Commission," which shall be constituted as hereinafter provided and which shall execute and enforce the provisions of this act.

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SEC. 301. It is the purpose of this Act, among other things, to maintain the control of the United States over all the channels of interstate and foreign radio transmission; and to provide for the use of such channels, but not the ownership thereof, by persons for limited periods of time, under licenses granted by Federal authority, and no such license shall be construed to create any right, beyond the terms, conditions, and periods of the license. No person shall use or operate any apparatus for the transmission of energy or communications or signals by radio (a) from one place in any Territory or possession of the United States or in the District of Columbia to another place in the same Territory, possession, or district; or (b) from any State, Territory, or possession of the United States, or from the District of Columbia to any other State, Territory, or possession of the United States; or (c) from any place in any State, Territory, or possession of the United States, or in the District of Columbia, to any place in any foreign country or to any vessel; or (d) within any State when the effects of such use extend beyond the borders of said State, or when interference is caused by such use or operation with the transmission of such energy, communications, or signals from within said State to any place beyond its borders, or from any place beyond its borders to any place within said State, or with the transmission or reception of such energy, communications, or signals from and/or to places beyond the borders of said State; or (e) upon any vessel or aircraft of the United States; or (f) upon any other mobile stations within the jurisdiction of the United States, except under and in accordance with this Act and with a license in that behalf granted under the provisions of this Act.

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SEC. 303. Except as otherwise provided in this Act, the Commission from time to time, as public convenience, interest, or necessity requires, shall—

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(1) Have authority to prescribe the qualifications of station operators, to classify them according to the duties to be performed, to fix the forms of such licenses, and to issue them to such citizens of the United States as the Commission finds qualified;

(m) (1) Have authority to suspend the license of any operator upon proof sufficient to satisfy the Commission that the licensee—

(A) Has violated any provision of any Act, treaty, or convention binding on the United States which the Commission is authorized to administer, or any regulation made by the Commission under any such Act, treaty, or convention; or

(B) Has failed to carry out a lawful order of the master or person lawfully in charge of the ship or aircraft on which he is employed; or

(C) Has willfully damaged or permitted radio apparatus or installations to be damaged; or

(D) Has transmitted superfluous radio communications or signals or communications containing profane or obscene words, language, or meaning, or has knowingly transmitted—

(1) False or deceptive signals or communications, or

(2) A call signal or letter which has not been assigned by proper authority to the station he is operating; or

(E) Has willfully or maliciously interfered with any other radio communications or signals; or

(F) Has obtained or attempted to obtain, or has assisted another to obtain or attempt to obtain, an operator's license by fraudulent means.

(2) No order of suspension of any operator's license shall take effect until fifteen days' notice in writing thereof, stating the cause for the proposed suspension, has been given to the operator licensee who may make written application to the Commission at any time within said fifteen days for a hearing upon such order. The notice to the operator licensee shall not be effective until actually received by him, and from that time he shall have fifteen days in which to mail the said application. In the event that physical conditions prevent mailing of the application at the expiration of the fifteen-day period, the application shall then be mailed as soon as possible thereafter, accompanied by a satisfactory explanation of the delay. Upon receipt by the Commission of such application for hearing, said order of suspension shall be held in abeyance until the conclusion of the hearing which shall be conducted under such rules as the Commission may prescribe. Upon the conclusion of said hearing the Commission may affirm, modify, or revoke said order of suspension.

(n) Have authority to inspect all radio installations associated with stations required to be licensed by any Act or which are subject to the provisions of any Act, treaty, or convention binding on the United States, to ascertain whether in construction, installation, and operation they conform to the requirements of the rules and regulations of the Commission, the provisions of any Act, the terms of any treaty or convention binding on the United States, and the conditions of the license or other instrument of authorization under which they are constructed, installed, or operated.

* * * * * * *

(r) Make such rules and regulations and prescribe such restrictions and conditions, not inconsistent with law, as may be necessary to carry out the provisions of this Act, or any international radio or wire communications treaty or convention, or regulations annexed thereto, including any treaty or convention insofar as it relates to the use of radio, to which the United States is or may hereafter become a party.

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SEC. 318. The actual operation of all transmitting apparatus in any radio station for which a station license is required by this Act shall be carried on only by a person holding an operator's license issued hereunder, and no person shall operate any such apparatus in such station except under and in accordance with an operator's license issued to him by the Commission: *Provided, however,* That the Commission if it shall find that the public interest, convenience, or necessity will be served thereby may waive or modify the foregoing provisions of this section for the operation of any station except (1) stations for which licensed operators are required by international agreement, (2) stations for which licensed operators are required for safety purposes, (3) stations engaged in broadcasting and (4) stations operated as common carriers on frequencies below thirty thousand kilocycles: *Provided further,* That the Commission shall have power to make special regulations governing the granting of licenses for the use of automatic radio devices and for the operation of such devices.

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SEC. 321. (a) The transmitting set in a radio station on shipboard may be adjusted in such a manner as to produce a maximum of radiation, irrespective of the amount of interference which may thus be caused, when such station is sending radio communications or signals of distress and radio communication relating thereto.

(b) All radio stations, including Government stations and stations on board foreign vessels when within the territorial waters of the United States, shall give absolute priority to radio communications or signals relating to ships in distress; shall cease all sending on frequencies which will interfere with hearing a radio communication or signal of distress, and, except when engaged in answering or aiding the ship in distress, shall refrain from sending any radio communications or signals until there is assurance that no interference will be caused with the radio communications or signals relating thereto, and shall assist the vessel in distress, so far as possible, by complying with its instructions.

SEC. 322. Every land station open to general public service between the coast and vessels or aircraft at sea shall, within the scope of its normal operations, be bound to exchange radio communications or signals with any ship or aircraft station at sea; and each station on shipboard or aircraft at sea shall, within the scope of its normal operations, be bound to exchange radio communications or signals with any other station on shipboard or aircraft at sea or with any land station open to general public service between the coast and vessels or aircraft at sea: *Provided,* That such exchange of radio communication shall be without distinction as to radio systems or instruments adopted by each station.

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SEC. 325. (a) No person within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto, nor shall any broadcasting station rebroadcast the program or any part thereof of another broadcasting station without the express authority of the originating station.

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SEC. 326. Nothing in this Act shall be understood or construed to give the Commission the power of censorship over the radio communications or signals transmitted by any radio station, and no regulation or condition shall be promulgated or fixed by the Commission which shall interfere with the right of free speech by means of radio communication. No person within the jurisdiction of the United States shall utter any obscene, indecent, or profane language by means of radio communication.

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SEC. 358. The radio installation, the operators, the regulation of their watches, the transmission and receipt of messages, and the radio service of the ship except as they may be regulated by law or international agreement, or by rules and regulations made in pursuance thereof, shall in the case of a ship of the United States be under the supreme control of the master.

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SEC. 501. Any person who willfully and knowingly does or causes or suffers to be done any act, matter, or thing, in this Act prohibited or declared to be unlawful, or who willfully and knowingly omits or fails to do any act, matter, or thing in this Act required to be done, or willfully and knowingly causes or suffers such omission or failure, shall, upon conviction thereof, be punished for such offense, for which no penalty (other than a forfeiture) is provided herein, by a fine of not more than $10,000 or by imprisonment for a term of not more than two years, or both.

SEC. 502. Any person who willfully and knowingly violates any rule, regulation, restriction, or condition made or imposed by the Commission under authority of this Act, or any rule, regulation, restriction, or condition made or imposed by any international radio or wire communications treaty or convention, or regulations annexed thereto, to which the United States is or may hereafter become a party, shall, in addition to any other penalties provided by law, be punished, upon conviction thereof, by a fine of not more than $500 for each and every day during which such offense occurs.

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Sec. 605. No person receiving or assisting in receiving, or transmitting, or assisting in transmitting, any interstate or foreign communication by wire or radio shall divulge or publish the existence, contents, substance, purport, effect, or meaning thereof, except through authorized channels of transmission or reception, to any person other than the addressee, his agent, or attorney, or to a person employed or authorized to forward such communication to its destination, or to proper accounting or distributing officers of the various communicating centers over which the communication may be passed, or to the master of a ship under whom he is serving, or in response to a subpena issued by a court of competent jurisdiction, or on demand of other lawful authority; and no person not being authorized by the sender shall intercept any communication and divulge or publish the existence, contents, substance, purport, effect, or meaning of such intercepted communication to any person; and no person not being entitled thereto shall receive or assist in receiving any interstate or foreign communication by wire or radio and use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; and no person having received such intercepted communication or having become acquainted with the contents, substance, purport, effect, or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the existence, contents, substance, purport, effect, or meaning of the same or any part thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto: *Provided,* That this section shall not apply to the receiving, divulging, publishing, or utilizing the contents of any radio communication broadcast, or transmitted by amateurs or others for the use of the general public, or relating to ships in distress.

(2) International Telecommunication Convention, Madrid, 1932

ARTICLE 24

§ 1. The contracting governments agree to take all the measures possible, compatible with the system of telecommunication used, with a view to insuring the secrecy of international correspondence.

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ARTICLE 34

§ 1. Stations carrying on radio communications in the mobile service shall be bound, within the scope of their normal operation, to exchange radio communications with one another irrespective of the radio system they have adopted.

ARTICLE 35

§ 1. All stations, regardless of their purpose, must, so far as possible, be established and operated in such a manner as not to interfere with the radio services or communications of either the other contracting governments, or the private operating agencies recognized by these contracting governments and of other duly authorized operating agencies which carry on radio-communication service.

ARTICLE 36

Stations participating in the mobile service shall be obliged to accept, with absolute priority, distress calls and messages regardless of their origin, to reply in the same manner to such messages, and immediately to take such action in regard thereto as they may require.

ARTICLE 37

The contracting governments agree to take the steps required to prevent the transmission or the putting into circulation of false or deceptive distress signals or distress calls, and the use, by a station, of call signals which have not been regularly assigned to it.

(3) General Radio Regulations (Cairo Revision, 1938)

Annexed to The International Telecommunications Convention (Madrid 1932)

ARTICLE 2

44 The administrations agree to take the necessary measures to prohibit and prevent:

45 (a) the unauthorized interception of radio communications not intended for the general use of the public;

46 (b) the divulging of the contents or of the mere existence, the publication or any use whatever, without authorization, of the radio communication mentioned in No. 45.

ARTICLE 3

47 § 1. (1) No transmitting station may be established or operated by any person or by any enterprise whatever without a special license issued by the government of the country to which the station in question is subject.

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ARTICLE 6

69 § 1. The waves emitted by a station must be kept on the authorized frequency as exactly as the state of the art permits, and their radiation must be as free as practically possible from all emissions not essential to the type of communication carried on.

71 § 2. (1) The state of the art in the various cases of operation is defined in appendixes 1, 2, and 3, concerning the exactitude of the frequency, the level of harmonics, and the width of the frequency band occupied.

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76 § 3. (1) The administrations shall frequently check the waves emitted by the stations under their jurisdiction to determine whether or not they comply with the provisions of the present Regulations.

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ARTICLE 9

203 § 2. The frequency of emission of mobile stations shall be verified as often as possible by the inspection service to which they are subject.

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ARTICLE 11

276 § 1. The radio service of a mobile station shall be placed under the supreme authority of the master or the person responsible for the ship, aircraft, or any other vehicle carrying the mobile station.

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278 § 3. The master or responsible person as well as any persons who may have knowledge of the text or simply the existence of radiotelegrams, or of any information acquired by means of the radio service, shall be bound by the obligation to observe and insure the secrecy of the correspondence.

ARTICLE 12

279 § 1. (1) The competent governments or administrations of countries where a mobile station calls, may demand the production of the license. The operator of the mobile station

or the person responsible for the station must submit to this verification. The license must be kept in such a way that it may be furnished withot delay. However, the production of the license may be replaced by a permanent posting in the station, of a copy of the license certified by the authority which has granted it.

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ARTICLE 17

374 § 2. (1) Before transmitting, any station must keep watch over a sufficient interval to assure itself that it will cause no harmful interference with the transmissions being made within its range; if such interference is likely, the station shall await the first stop in the transmission which it may disturb.

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ARTICLE 22

525 § 1. (1) The transmission of unnecessary or unidentified signals or correspondence shall be forbidden to all stations.

527 (2) Tests and experiments shall be permitted in mobile stations if they do not interfere with the service of other stations. As for stations other than mobile stations, each administration shall judge, before authorizing them, whether or not the proposed tests or experiments are likely to interfere with the service of other stations.

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ARTICLE 24

542 1. No provision of these Regulations shall prevent a mobile station in distress from using any means available to it for drawing attention, signalling its position, and obtaining help.

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548 3. (2) Aircraft. Any aircraft in distress must transmit the distress call on the watching-wave of the land or mobile stations capable of helping it; when the call is addressed to stations of the maritime service, the waves to be used are the distress-wave or watching-wave of these stations.

549 § 4. (1) In radiotelegraphy, the distress signal shall consist of the group . . . — — — . . ., transmitted as one signal, in which the dashes must be emphasized so as to be distinguished clearly from the dots.

550 In radiotelephony, the distress signal shall consist of the spoken expression Mayday (corresponding to the French pronunciation of the expression "m'aider").

551 (2) These distress signals shall announce that the ship, aircraft, or any other vehicle which sends the distress signal is threatened by serious and imminent danger and requests immediate assistance.

* * * * * * *

555 § 5. (4) This call shall have absolute priority over other transmissions. All stations hearing it must immediately cease all transmission capable of interfering with the distress traffic and must listen on the wave used for the distress call. This call must not be sent to any particular station and shall not require an acknowledgment of receipt.

556 § 6. (1) The distress call must be followed as soon as possible by the distress message. This message shall include the distress call followed by the name of the ship, aircraft, or the vehicle in distress, information regarding the position of the latter, the nature of the distress and the nature of the help requested, and any other further information which might facilitate this assistance.

557 (2) When, in its distress message, an aircraft is unable to signal its position, it shall endeavor after the transmission of the incomplete message to send its call signal long enough so that the radio direction-finding stations may determine its position.

558 § 7. (1) As a general rule, a ship or aircraft at sea shall signal its position in latitude and longitude (Greenwich), using figures, for the degrees and minutes, accompanied by one

of the words North or South and one of the words East or West. A period shall separate the degrees from the minutes. In some cases, the true bearings and the distance in nautical miles from some known geographical point may be given.

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560 (3) As a general rule, an aircraft flying over land shall signal its position by the name of the nearest locality, its approximate distance from this point, accompanied, according to the case, by one of the words North, South, East, or West, or, in some cases, words indicating intermediate directions.

561 § 8. The distress call and message shall be sent only by order of the master or person responsible for the ship, aircraft, or other vehicle carrying the mobile station.

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569 § 11 (1) Stations of the mobile service which receive a distress message from a mobile station which is unquestionably in their vicinity, must acknowledge receipt thereof at once (see Nos. 587, 588, and 589). If the distress call has not been preceded by an auto-alarm signal, these stations may transmit this auto-alarm signal with the authorization of the authority responsible for the station (for mobile stations, see No. 276), taking care not to interfere with the transmission of the acknowledgment of the receipt of said message by other stations.

570 (2) Stations of the mobile service which receive a distress message from a mobile station which unquestionably is not in their vicinity, must wait a short period of time before acknowledging receipt thereof, in order to make it possible for stations nearer to the mobile station in distress to answer and acknowledge receipt without interference.

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573 § 14. The control of distress traffic shall devolve upon the mobile station in distress or upon the mobile station which, by application of the provisions of No. 567, has sent the distress call. These stations may delegate the control of the distress traffic to another station.

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604 § 22. (2) In radiotelephony the urgent signal shall consist of three transmissions of the expression PAN (corresponding to the French pronunciation of the word "panne"); it shall be transmitted before the call.

605 (3) The urgent signal shall indicate that the calling station has a very urgent message to transmit concerning the safety of a ship, an aircraft, or another vehicle, or concerning the safety of some person on board or sighted from on board.

606 (4) In the aeronautical service, the urgent signal PAN shall be used in radiotelegraphy and in radiotelephony to indicate that the aircraft transmitting it is in trouble and is forced to land, but that it is not in need of immediate help. This signal should, so far as possible, be followed by a message giving additional information.

607 (5) The urgent signal shall have priority over all other communications, except distress communications, and all mobile or land stations hearing it must take care not to interfere with the transmission of the message which follows the urgent signal.

608 (6) In case the urgent signal is used by a mobile station, this signal must, as a general rule, subject to the provisions of No. 606, be addressed to a definite station.

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612 § 25. (1) The urgent signal may be transmitted only with the authorization of the master or of the person responsible for the ship, aircraft, or any other vehicle carrying the mobile station.

613 (2) In the case of a land station, the urgent signal may be transmitted only with the approval of the responsible authority.

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615 § 26. (1) In radiotelegraphy, the safety signal shall consist of the group TTT, transmitted three times, with the letters of each group, as well as the consecutive groups, well separated. This signal shall be followed by the word DE and three transmissions of the call signal of the station sending it. It announces that this station is about to transmit a message concerning the safety of navigation or giving important meteorological warnings.

616 (2) In radiotelephony, the word Security (corresponding to the French pronunciation of the word "sécurité") repeated three times, shall be used as the safety signal.

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619 § 28. (2) All stations hearing the safety signal must continue listening on the wave on which the safety signal has been sent until the message so announced has been completed; they must moreover keep silence on all waves likely to interfere with the message.

ARTICLE 26

Order of Priority of Communications in the Mobile Service

653 The order of priority of radio communications in the mobile service shall be as follows:

1. Distress calls, distress messages, and distress traffic;
2. Communications preceded by an urgent signal;
3. Communications preceded by a safety signal;
4. Communications relative to radio direction-finding bearings;
5. Government radiotelegrams for which priority right has not been waived;
6. All other communications.

(4) Extracts from Rules and Regulations of the Federal Communications Commission

Chapter I—Rules of Practice and Procedure

Sec. 1.391 *Under Title III of the Act.* Any licensee receiving official notice of a violation of the terms of the Communications Act of 1934, any legislative act, Executive Order, treaty to which the United States is a party, or the Rules and Regulations of the Federal Communications Commission, shall, within three days from such receipt, send a written answer direct to the Federal Communications Commission at Washington, D. C., and a copy thereof to the office of the Commission originating the official notice when the originating office is other than the office of the Commission in Washington, D. C. *Provided, however,* That if an answer cannot be sent nor an acknowledgment made within such three-day period by reason of illness or other unavoidable circumstances, acknowledgment and answer shall be made at the earliest practicable date with a satisfactory explanation of the delay. The answer to each notice shall be complete in itself and shall not be abbreviated by reference to other communications or answers to other notices. If the notice relates to some violation that may be due to the physical or electrical characteristics of transmitting apparatus, the answer shall state fully what steps, if any, are taken to prevent future violations, and if any new apparatus is to be installed, the date such apparatus was ordered, the name of the manufacturer, and promised date of delivery. If the installation of such apparatus requires a construction permit, the file number of the application shall be given, or if a file number has not been assigned by the Commission, such identification as will permit of ready reference. If the notice of violation relates to some lack of attention or improper operation of the transmitter, the name and license number of the operator in charge shall be given.

* * * * * * *

Sec. 1.411 *Order of suspension.* No order of suspension of any operator's license shall take effect until fifteen days' notice in writing thereof, stating the cause for the proposed suspension, has been given to the operator licensee who may make written application to the Commission at any time within said fifteen days for a hearing upon such order. The notice to the operator licensee shall not be effective until actually received by him, and from that time he shall have fifteen days in which to mail the said application. In the event that physical conditions prevent mailing of the application at the expiration of the fifteen-day period, the application shall then be mailed as soon as possible thereafter, accompanied by a satisfactory explanation of the delay. Upon receipt by the Commission of such application for hearing, said order of suspension shall be held in abeyance until the conclusion of the hearing which shall be conducted under such rules as the Commission shall deem appropriate. Upon the conclusion of said hearing the Commission may affirm, modify, or revoke said order of suspension.

SEC. 1.412 *Proceedings.* Proceedings for the suspension of an operator's license shall in all cases be initiated by the entry of an order of suspension. Respondent will be given notice thereof together with notice of his right to be heard and to contest the proceeding. The effective date of the suspension will not be specified in the original order but will be fixed by subsequent motion of the Commission in accordance with the conditions specified above. Notice of the effective date of suspension will be given respondent, who shall send his operator license to the office of the Commission in Washington, D. C., on or before the said effective date, or, if the effective date has passed at the time notice is received, the license shall be sent to the Commission forthwith.

PART 2—GENERAL RULES AND REGULATIONS

SEC 2.48 *Station inspection.* The licensee of any radio station shall make the station available for inspection by representatives of the Commission at any reasonable hour and under the regulations governing the class of station concerned.

SEC. 2.52 *Operator license, posting of.* The original license of each station operator shall be posted at the place where he is on duty or kept in his possession in the manner specified in the regulations governing the class of station concerned.

SEC. 2.53 *Operators' place of duty. a.* Except as may be provided in the rules governing a particular class of station, one or more licensed operators of the grade specified by these rules and regulations shall be on duty at the place where the transmitting apparatus of each station is located and in actual charge thereof whenever it is being operated: *Provided, however,* That:

2. In the case of two or more stations, except amateur and broadcast, licensed in the name of the same person to use frequencies above 30,000 kilocycles only, a licensed radio operator of any class except amateur, radiotelephone third class, or holder of restricted operator permit who has the station within his effective control, may be on duty at any point within the communication range of such stations in lieu of the transmitter location or control point during the actual operation of the transmitting apparatus and shall supervise the emissions of all such stations so as to insure the proper operation in accordance with the station license.

SEC. 2.54 *Retention of radio station logs.* Logs of a radio station, when required elsewhere in these rules and regulations to be made or kept, shall be retained by the licensee for a period of one year unless otherwise provided by the rules governing the particular service or class of station concerned: *Provided, however,* That logs involving communications incident to a disaster or which include communications incident to or involved in an investigation by the Commission and concerning which the licensee has been notified, shall be retained by the licensee until specifically authorized in writing by the Commission to destroy them: *Provided, further,* That logs incident to or involved in any claim or complaint of which the licensee has notice shall be retained by the licensee until such claim or complaint has been fully satisfied or until the same has been barred by statute limiting the time for the filing of suits upon such claims.

SEC. 2.55 *Logs, by whom kept.* Each log shall be kept by the person or persons competent to do so, having actual knowledge of the facts required, who shall sign the log when starting duty and again when going off duty. The logs shall be made available upon request by an authorized representative of the Commission.

SEC. 2.57 *Correction of logs.* No log or portion thereof shall be erased, obliterated, or wilfully destroyed within the period of retention provided by the rules. Any necessary correction may be made only by the person originating the entry who shall strike out the erroneous portion, initial the correction made and indicate the date of correction.

SEC. 2.58 *Rough logs.* Rough logs may be transcribed into condensed form, but in such case the original log or memoranda and all portions thereof shall be preserved and made a part of the complete log.

SEC. 2.59 *Distress messages.* Each station licensee shall give absolute priority to radio communications or signals relating to ships or aircraft in distress; shall cease all sending on frequencies which will interfere with hearing a radio communication or signal of distress and except when engaged in answering or aiding the ship or aircraft in distress; shall refrain from sending any radio communications or signals until there is assurance that no interference will be caused with the radio communications or signals relating thereto, and shall assist the vessel in distress, so far as possible, by complying with its instructions.

SEC. 2.60 *Control of distress traffic.* The control of distress traffic shall devolve upon the mobile station in distress or upon the station which by application of the provisions of Sec. 2.61 has sent the distress call. These stations may delegate the control of the distress traffic to another station.

SEC. 2.61 *Retransmission of distress message.* Any station which becomes aware that a mobile station is in distress may transmit the distress message in the following cases:

a. When the station in distress is not itself in a position to transmit the message.

b. In the case of mobile stations, when the Master or the person in charge of the ship, aircraft, or other vehicle carrying the station which intervenes believes that further help is necessary.

c. In the case of other stations, when directed to do so by the station in control of distress traffic or when it has reason to believe that a distress call which it has interpreted has not been received by any station in a position to render aid.

SEC. 2.62 *Resumption of operation after distress.* No station having been notified to cease operation shall resume operation on frequency or frequencies which may cause interference until notified by the station issuing the original notice that the station involved will not interfere with distress traffic as it is then being routed or until the receipt of a general notice that the need for handling distress traffic no longer exists.

SEC. 2.63 *Operation during emergency.* The licensee of any station, except amateurs, may, during a period of emergency in which the normal communication facilities are disrupted as a result of hurricane, flood, earthquake, or similar disaster, utilize such station for emergency communication service in communicating in a manner other than that specified in the station license, provided (1) that as soon as possible after the beginning of such emergency use notice be sent to the Commission in Washington, D. C., and to the Inspector in Charge of the district in which the station is located stating the nature of the emergency and the use to which the station is being put, and (2) that the emergency use of the station shall be discontinued as soon as substantially normal communication facilities are again available and the Commission in Washington, D. C., and the Inspector in Charge be notified immediately when such special use of the station is terminated. The Commission may at any time order the discontinuance of such service.

SEC. 2.75 *Frequency measurement.* The licensee of each station shall provide means for the measurement of the station frequency. The measurement of the station frequency shall be made by a means independent of the frequency control of the transmitter and shall be conducted in accord with the regulations governing the class of station concerned.

SEC. 2.80 *Operating power tolerance.* The operating power of all radio stations shall be maintained within the following tolerance of the assigned power:

1. When the maximum power only is specified, the operating power shall not be greater than necessary to carry on the service and in no event more than 5 per cent above the maximum power specified.

2. When an exact power is specified, the operating power shall not be more than 5 percent above or less than 10 percent below such power.

PART 13—RULES GOVERNING COMMERCIAL RADIO OPERATORS

SEC. 13.61 *Operators' authority.* The various classes of commercial operator licenses issued by the Commission authorize the holders thereof to operate radio stations, except amateur, as follows:

(e) *Restricted radiotelephone operator permit.* Any station while using type A–0, A–3, or A–4 emission: *Provided,* That,

(1) Such operator is prohibited from making adjustments that may result in improper transmitter operation.

(2) The equipment is so designed that none of the operations necessary to be performed

during the course of normal rendition of service may cause off-frequency operation or result in any unauthorized radiation.

(3) Any needed adjustments of the transmitter that may affect the proper operation of the station are regularly made by or in the presence of an operator holding a first- or second-class license, either telephone or telegraph, who shall be responsible for the proper operation of the equipment.

Exceptions:

(1) The permit is not valid for the operation of any of the various classes of broadcast stations other than a relay broadcast station.

(2) The permit is not valid for the operation of a coastal telephone station or a coastal harbor station other than in the Territory of Alaska.

(3) The permit is not valid for the operation of a ship station licensed to use type A–3 emission for communication with coastal telephone stations.

(f) *Restricted radiotelegraph operator permit.* Any station while using type B, A–0, A–1, A–2, A–3, or A–4 emission: *Provided,* That, in the case of equipment designed for and using type A–3 or A–4 emission.

(1) Such operator is prohibited from making adjustments that may result in improper transmitter operation.

(2) The equipment is so designed that none of the operations necessary to be performed during the course of normal rendition of service may cause off-frequency operation or result in any unauthorized radiation.

(3) Any needed adjustments of the transmitter which may affect proper operation of the station are regularly made by or in the presence of an operator holding a first- or second-class license, either telephone or telegraph, who shall be responsible for the proper operation of the equipment.

Exceptions:

(1) The permit is not valid for the operation of any of the various classes of broadcast stations other than a relay broadcast station.

(2) The permit is not valid for the operation of a ship station licensed to use type A–3 emission for communication with coastal telephone stations.

(3) The license is not valid for the operation of a radiotelegraph station on board a vessel required by treaty or statute to be equipped with a radio installation.

(4) The license is not valid for the operation of any ship telegraph, coastal telegraph, or marine-relay station open to public correspondence.

SEC. 13.63 *Operator's responsibility.* The licensed operator responsible for the maintenance of a transmitter may permit other persons to adjust a transmitter in his presence for the purpose of carrying out tests or making adjustments requiring specialized knowledge or skill, provided that he shall not be relieved thereby from responsibility for the proper operation of the equipment.

SEC. 13.71 *Issue of duplicate license.* An operator whose license or permit has been lost, mutilated, or destroyed, shall immediately notify the Commission. A sworn application for duplicate should be submitted to the office of issue embodying a statement attesting to the facts thereof. If a license has been lost, the applicant must state that reasonable search has been made for it, and further, that in the event it be found either the original or the duplicate will be returned for cancellation. The applicant must also give a statement of the service that has been obtained under the lost license.

SEC. 13.72 *Exhibiting signed copy of application.* When a duplicate operator license or permit has been requested, or request for renewal upon service has been made, the operator shall exhibit in lieu thereof a signed copy of the application for duplicate, or renewal, which has been submitted by him.

SEC. 13.75 *Posting license or verified statement.* The holder of a radiotelegraph or radiotelephone first- or second-class license who is employed as a service and maintenance operator at stations operated by holders of Restricted Operator Permits shall post at such station his operator license or a verified statement from the Commission in lieu thereof.

APPENDIX III

TABLE 1. ABBREVIATIONS TO BE USED IN RADIO COMMUNICATIONS—Q CODE—ABBREVIATIONS TO BE USED IN ALL SERVICES[1, 2]

Abbreviation	Question	Answer or statement
QRA	What is the name of your station?	The name of my station is . . .
QRB	At what approximate distance are you from my station?	The approximate distance between our stations is . . . nautical miles (*or* . . . kilometers).
QRC	By what private operating enterprise (*or* government administration) are the accounts for charges of your station settled?	The accounts for charges of my station are settled by the . . . private operating enterprise (*or* by the government administration of . . .).
QRD	Where are you going and where do you come from?	I am going to . . . and I come from . . .
QRG	Will you tell me what my exact frequency (wave length) is in kilocycles (*or* meters)?	Your exact frequency (wave length) is . . . kilocycles (*or* . . . meters).
QRH	Does my frequency (wave length) vary?	Your frequency (wave length) varies.
QRI	Is the tone of my transmission regular?	The tone of your transmission varies.
QRJ	Are you receiving me badly? Are my signals weak?	I cannot receive you. Your signals are too weak.
QRK	What is the legibility of my signals (*1 to 5*)?	The legibility of your signals is . . . (*1 to 5*).
QRL	Are you busy?	I am busy (*or* I am busy with . . .). Please do not interfere.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are you troubled by static?	I am troubled by static.
QRO	Must I increase the power?	Increase the power.
QRP	Must I decrease the power?	Decrease the power.
QRQ	Must I transmit faster?	Transmit faster (. . . words per minute).
QRS	Must I transmit more slowly?	Transmit more slowly (. . . words per minute).
QRT	Must I stop transmission?	Stop transmission.
QRU	Have you anything for me?	I have nothing for you.
QRV	Are you ready?	I am ready.
QRW	Must I advise . . . that you are calling him on . . . kilocycles (*or* . . . meters)?	Please advise . . . that I am calling him on . . . kilocycles (*or* . . . meters).
QRX	Must I wait? When will you call me again?	Wait (*or* Wait until I have finished communicating with . . .). I shall call you again at . . . o'clock (*or* immediately).

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[1] Abbreviations take the form of questions when they are followed by a question mark.

[2] The series of signals QA to QD and QF to QN are reserved for the special code of the aeronautical service.

TABLE 1. ABBREVIATIONS TO BE USED IN RADIO COMMUNICATIONS—Q CODE—ABBREVIATIONS TO BE USED IN ALL SERVICES—*Continued*

Abbreviation	Question	Answer or statement
QRY	Which is my turn?......................	Your turn is number . . . (*or according to any other indication*).
QRZ	By whom am I being called?............	You are being called by . . .
QSA	What is the strength of my signals (*1 to 5*)?	The strength of your signals is (*1 to 5*).
QSB	Does the strength of my signals vary?.....	The strength of your signals varies.
QSD	Is my keying correct; are my signals distinct?	Your keying is incorrect; your signals are bad.
QSG	Must I transmit . . . telegrams (*or* one telegram) at a time?	Transmit . . . telegrams (*or* one telegram) at a time.
QSJ	What is the charge to be collected per word to . . . including your internal telegraph charge?	The charge to be collected per word to . . . is . . . francs, including my internal telegraph charge.
QSK	Must I continue the transmission of all my traffic; I can hear you between my signals?	Continue the transmission of all your traffic; I shall interrupt you if necessary.
QSL	Can you acknowledge receipt?...........	I am acknowledging receipt.
QSM	Must I repeat the last telegram which I transmitted to you?	Repeat the last telegram which you transmitted to me.
QSO	Can you communicate with . . . directly (*or* through . . .)?	I can communicate with . . . directly (*or* through . . .).
QSP	Will you relay to . . . free of charge?.....	I will relay to . . . free of charge.
QSR	Has the distress call received from . . . been attended to?	The distress call received from . . . has been attended to by . . .
QSU	Must I transmit (*or* answer) on . . . kilocycles (*or* meters) and/or on waves of type A1, A2, A3, or B?	Transmit (*or* answer) on . . . kilocycles (*or* . . . meters) and/or waves of type A1, A2, A3, or B.
QSV	Must I transmit a series of V's?..........	Transmit a series of V's.
QSW	Do you wish to transmit on . . . kilocycles (*or* . . . meters), and/or on waves of type A1, A2, A3, or B?	I am going to transmit (*or* I shall transmit) on . . . kilocycles (*or* . . . meters), and/or on waves of type A1, A2, A3, or B.
QSX	Will you listen to . . . (*call signal*) on . . . kilocycles (*or* . . . meters)?	I am listening to . . . (*call signal*) on . . . kilocycles (*or* . . . meters).
QSY	Must I shift to transmission on . . . kilocycles (*or* . . . meters), without changing the type of wave? *or* Must I shift to transmission on another wave?	Shift to transmission on . . . kilocycles (*or* . . . meters) without changing the type of wave Shift to transmission on another wave.
QSZ	Must I transmit each word or group twice?	Transmit each word or group twice.
QTA	Must I cancel telegram no. . . . as if it had not been transmitted?	Cancel telegram no. . . . as if it had not been transmitted.
QTB	Do you agree with my word count?.......	I do not agree with your word count; I shall repeat the first letter of each word and the first figure of each number.
QTC	How many telegrams have you to transmit?	I have . . . telegrams for you (*or* for . . .).

TABLE 1. ABBREVIATIONS TO BE USED IN RADIO COMMUNICATIONS—Q CODE—ABBREVIATIONS TO BE USED IN ALL SERVICES—*Continued*

Abbreviation	Question	Answer or statement
QTE[3]	What is my true bearing in relation to you? *or* What is my true bearing in relation to . . . (*call signal*)? *or* What is the true bearing of . . . (*call signal*) in relation to . . . (*call signal*)?	Your true bearing in relation to me is . . . degrees *or* Your true bearing in relation to . . . (*call signal*) is . . . degrees at . . . (*time*) *or* The true bearing of . . . (*call signal*) in relation to . . . (*call signal*) is . . . degrees at . . . (*time*).
QTF	Will you give me the position of my station on the basis of bearings taken by the radio direction-finding stations which you control?	The position of your station on the basis of bearings taken by the radio direction-finding stations which I control is . . . latitude, . . . longitude.
QTG	Will you transmit your call signal during 50 seconds ending with a 10-second dash, on . . . kilocycles (*or* . . . meters) so that I may take your radio direction-finding bearings?	I will transmit my call signal during 50 seconds, ending with a 10-second dash, on . . . kilocycles (*or* . . . meters) so that you may take my radio direction-finding bearings.
QTH	What is your position in latitude and in longitude (*or according to any other indication*)?	My position is . . . latitude, . . . longitude (*or according to any other indication*).
QTI	What is your true course?	My true course is . . . degrees.
QTJ	What is your speed?	My speed is . . . knots (*or* . . . kilometers) per hour.
QTM	Transmit radio signals and submarine sound signals to enable me to determine my bearing and my distance.	I am transmitting radio signals and submarine sound signals to enable you to determine your bearing and your distance.
QTO	Have you left dock (*or* port)?	I have left dock (*or* port).
QTP	Are you going to enter dock (*or* port)?	I am going to enter dock (*or* port).
QTQ	Can you communicate with my station by the International Code of Signals?	I am going to communicate with your station by the International Code of Signals.
QTR	What is the exact time?	The exact time is . . .
QTU	What are the hours during which your station is open?	My station is open from . . . to . . .
QUA	Have you any news from . . . (*call signal of the mobile station*)?	This is the news from . . . (*call signal of the mobile station*).
QUB	Can you give me, in the following order, information concerning: visibility, height of clouds, ground wind at . . . (*place of observation*)?	This is the information requested: . . . .
QUC	What is the last message you received from . . . (*call signal of the mobile station*)?	The last message I received from . . . (*call signal of the mobile station*) is . . .
QUD	Have you received the urgent signal transmitted by . . . (*call signal of the mobile station*)?	I have received the urgent signal transmitted by . . . (*call signal of the mobile station*) at . . . (*time*).

[3] In certain aeronautical services, "true course" and "true bearing" are called "geographic course" and "geographic bearing."

TABLE 1. ABBREVIATIONS TO BE USED IN RADIO COMMUNICATIONS—Q CODE—ABBREVIATIONS TO BE USED IN ALL SERVICES—*Continued*

Abbreviation	Question	Answer or statement
QUF	Have you received the distress signal sent by . . . (*call signal of the mobile station*)?	I have received the distress signal sent by . . . (*call signal of the mobile station*) at . . . (*time*).
QUG	Will you be forced to come down on water (*or* on land)?	I am forced to come down on water (*or* on land) at . . . (*place*).
QUH	Will you give me the present barometric pressure at sea level?	The present barometric pressure at sea level is . . . (*units*).
QUJ [3]	Will you please indicate the proper course to steer toward you, with no wind?	The proper course to steer toward me, with no wind, is . . . degrees at . . . (*time*).
QUK	Can you tell me the condition of the sea observed at . . . (*place or coordinates*)?	The sea at . . . (*place or coordinates*) *is* . . .
QUL	Can you tell me the surge observed at . . . (*place or coordinates*)?	The surge at . . . (*place or coordinates*) *is* . . .
QUM	Is the distress traffic ended?	The distress traffic is ended.

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[3] In certain aeronautical services, "true course" and "true bearing" are called "geographic course" and "geographic bearing."

TABLE 2. SCALE USED TO EXPRESS STRENGTH OR LEGIBILITY OF SIGNALS

Strength	*Legibility*
QSA 1 = scarcely perceptible.	QRK 1 = unreadable.
QSA 2 = weak.	QRK 2 = readable now and then.
QSA 3 = fairly good.	QRK 3 = readable, but with difficulty.
QSA 4 = good.	QRK 4 = readable.
QSA 5 = very good.	QRK 5 = perfectly readable.

TABLE 3. MISCELLANEOUS ABBREVIATIONS

Abbreviation	Meaning
C	Yes.
N	No.
P	Announcing private telegram in the mobile service (to be used as a prefix).
W	Word *or* words.
AA	All after . . . (to be used after a question mark to request a repetition).
AB	All before . . . (to be used after a question mark to request a repetition).
AL	All that has just been transmitted (to be used after a question mark to request a repetition).
AS	Waiting period.
BN	All between . . . (to be used after a question mark to request a repetition).
BQ	Answer to RQ.
CL	I am closing my station.
CS	Call signal (to be used in requesting that call signal be given or repeated).
DB	I cannot give you a bearing, you are not in the calibrated sector of this station.
DC	The minimum of your signal is suitable for the bearing.

TABLE 3. MISCELLANEOUS ABBREVIATIONS—*Continued*

Abbreviation	Meaning
DF	Your bearing at . . . (*time*) was . . . degrees, in the doubtful sector of this station, with a possible error of two degrees.
DG	Please advise me if you find an error in the bearing given.
DI	Doubtful bearing due to the bad quality of your signal.
DJ	Doubtful bearing due to interference.
DL	Your bearing at . . . (*time*) was . . . degrees, in the uncertain sector of this station.
DO	Doubtful bearing. Request another bearing later, or at . . . (*time*).
DP	Beyond 50 miles, possible error of bearing can attain two degrees.
DS	Adjust your transmitter, your minimum signal is too broad.
DT	I cannot give you a bearing, your minimum signal is too broad.
DY	This is a two-way station, what is your approximate direction, in degrees, in relation to this station?
DZ	Your bearing is reciprocal (to be used only by the control station of a group of radio direction-finding stations when addressing other stations of the same group).
ER	Here . . . (to be used before the name of the mobile station in the transmission of routing indications).
GA	Resume transmission (to be used more especially in the fixed service).
JM	If I may transmit, make a series of dashes. To stop my transmission, make a series of dots [not to be used on 500 kc. (600 m.)].
MN	Minute or minutes (to be used to indicate the duration of the waiting period).
NW	I am resuming transmission (to be used more especially in the fixed service).
OK	We agree.
RG	Announcing a request.
SA	Announcing the name of an aircraft station (to be used in transmitting transit data).
SF	Announcing the name of an aeronautical station.
SN	Announcing the name of a coast station.
SS	Announcing the name of a ship station (to be used in transmitting transit data).
TR	To announce sending of indications concerning a mobile station.
TU	Thank you for the cooperation given.
UA	Do we agree?
WA	Word after . . . (to be used after a question mark to request a repetition).
WB	Word before . . . (to be used after a question mark to request a repetition).
XS	Static.
YS	See your service notice.
ABV	Repeat (*or* I repeat) the figures in abbreviated form.
ADR	Address (to be used after a question mark to request a repetition).
CFM	Confirm (*or* I confirm).
COL	Collate (*or* I collate).
ITP	The punctuation counts.
MSG	Announcing a telegram concerning the service on board (to be used as a prefix).
NIL	I have nothing to transmit to you (to be used after an abbreviation of code Q to show that the answer to the question asked is in the negative).
PBL	Preamble (to be used after a question mark to request a repetition).
REF	Reference to . . . (*or* Refer to . . .).
RPT	Repeat (*or* I repeat) (to be used in requesting or giving repetition of all or part of the traffic, the abbreviation to be followed by the corresponding indications).
SIG	Signature (to be used after a question mark to request a repetition).
SVC	Announcing a service telegram concerning private traffic (to be used as a prefix).
TFC	Traffic.
TXT	Text (to be used after a question mark to request a repetition).

TABLE 4. INTERNATIONAL MORSE CODE, WITH EXTRACTS FROM THE LIST OF PUNCTUATIONS AND OTHER SIGNS CONTAINED IN THE TELEGRAPH REGULATIONS OF THE CAIRO CONFERENCES, 1938

LETTERS

a · —
b — · · ·
c — · — ·
d — · ·
e ·
f · · — ·
g — — ·
h · · · ·
i · ·
j · — — —
k — · —
l · — · ·
m — —
n — ·
o — — —
p · — — ·
q — — · —
r · — ·
s · · ·
t —
u · · —
v · · · —
w · — —
x — · · —
y — · — —
z — — · ·

FIGURES

1 · — — — —
2 · · — — —
3 · · · — —
4 · · · · —
5 · · · · ·
6 — · · · ·
7 — — · · ·
8 — — — · ·
9 — — — — ·
0 — — — — —

PUNCTUATION AND OTHER SIGNS

Period	.	· — · — · —
Comma	,	— — · · — —
Colon	:	— — — · · ·
Question mark, or request for repetition of a transmission not understood	?	· · — — · ·
Apostrophe	'	· — — — — ·
Dash or hyphen	—	— · · · · —
Fraction bar	/	— · · — ·
Parenthesis (before and after words)	( )	— · — — · —
Underscore (before and after words or part of sentence)		· · — — · —
Equal sign	=	— · · · —
Understood		· · · — ·
Error		· · · · · · · ·
Cross or end-of-telegram or end-of-transmission signal		· — · — ·
Invitation to transmit		— · —
Wait		· — · · ·
End of work		· · · — · —
Starting signal (beginning every transmission)		— · — · —
Separation signal for transmission of fractional numbers (between the ordinary fraction and the whole number to be transmitted) and for groups consisting of figures and letters (between the figure groups and the letter groups)		· — · · —

The following optional letters and signals may be used exceptionally on connections between countries allowing them:

ä · — · —
á or å · — — · —
ch — — — —
é · · — · ·
ñ — — · — —
ö — — — ·
ü · · — —

In transmitting numbers involving a fraction, the separation signal must, in order to avoid confusion, be transmitted before or after the fraction, as the case may be.

Examples. Instead of 1 1/16, transmit 1 · — ·· — 1/16 in order not to have it read 11/16; instead of 3/4 8, transmit 3/4 · — ·· — 8 in order not to have it read 3/48; instead of 2 1/2 2, transmit 2 · — ·· — 1/2 · — ·· — 2 in order not to have it read 21/22.

A group consisting of figures and letters must be transmitted by inserting the separation signal (· — ·· —) between the figure group and the letter group.

APPENDIX IV

MISCELLANEOUS

Automatic Alarm Device.*

(*a*) *Frequency Band of the Auto Alarm Receiver.* The regulations of the "International Convention for the Safety of Life at Sea" which apply to radio aboard ship and particularly to "watches" in the radio room of cargo vessels make it compulsory for cargo vessels of over 5,500 gross tonnage, not fitted with an auto alarm, to keep a continuous watch, while under way, by means of an operator or operators. On ships which are fitted with an auto alarm, this apparatus must be in operation when the operator is not on watch. The alarm signal, consisting of a series of dashes and spaces, when intercepted passes through a specially designed receiver which has a uniform sensitivity over a frequency range from 487.5 to 512.5 kc., or a total band width of 25 kc. The normal distress frequency is 500 kc., but provision is made for the auto alarm receiver to accept signals outside the exact frequency, thereby permitting some variation in the adjustment of the radio transmitter on the vessel in distress. After the radio alarm signal passes through the receiver it controls the selector mechanism. To allow for reasonable variations in the timing of the alarm signal, the selector is designed to accept dashes having a duration of 3.5 to 4.5 seconds and spaces from 0.1 to 1.5 seconds. A normal dash has a duration of 4 seconds and a normal space of 1 second. Routine daily tests of the alarm apparatus while the vessel is under way is required by the rules of the Federal Communications Commission. For this test the operator sends a local alarm signal through the circuits by referring to the sweep seconds hand of the station's clock to time the dashes and spaces, and together with suitable meters and controls he can check the overall performance. After every such test the operator is required to make an entry in the radio log stating that he has performed the test.

(*b*) *Auto Alarm Receiver.* Figure 113 illustrates schematically the tube and circuit layout of the superheterodyne receiver which consists of five tubes and associated tuned circuits required to give the necessary amplification and selectivity. An incoming radio alarm signal between 487.5 and 512.5 kc., with attenuation of signals outside these limits, is applied to the mixer-oscillator tube where it is mixed with the local oscillator frequency of 1,600 kc. The difference beat between signal and oscillator frequency, or 1,087.5 and 1,112.5 kc., is amplified by two intermediate-frequency stages, utilizing super-control pentode tubes, and then applied to the diode detector. The d-c voltage developed across diode resistor R-1 is used to control the grid circuit of the d-c amplifier, RCA-1611, and a relay in this tube's plate circuit either initiates or stops selector action. A wavetrap directly in the antenna lead is provided for the attenuation of strong broadcast signals from stations operating on frequency assignments in the pass-band accepted by the intermediate-frequency amplifiers. A 500-microvolt signal between the limits of 487.5 and 512.5 kc., irrespective of modulation or modulation frequency and including spark signals, must produce sufficient voltage of the polarity shown on the diode load resistor R_1 to control the grid of the d-c amplifier tube. This tube has a "no signal" plate current value of approximately 7 milliamperes; thus signal relay No. 4 is normally energized. The 500-microvolt signal then reduces this relay current to below its drop-out value of 3 to 4 milliamperes. If the signal remains long enough, selector action obtains as explained later. A signal stronger than 500 microvolts merely produces plate current cutoff in the signal relay tube. "Downwards" operation of the signal relay is desirable inasmuch as a strong signal does not excessively deflect the milliammeter, shown as A. The relay operates on breaks of one-tenth second or less.

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* The detailed explanation herewith reprinted covering operation of a Radiomarine Auto Alarm was obtained through the courtesy of *RCA Review* and the authors of the article, I. F. Byrnes and H. B. Martin of the Engineering Department, Radiomarine Corporation of America.

(*c*) *How to Adjust for Desired Sensitivity.* Sensitivity control R_3 is provided for adjustment to optimum sensitivity, consistent with the prevailing noise level caused by atmospherics and man-made static. Thus to adjust for proper operation, the sensitivity control would be turned to its maximum counter-clockwise position, which gives minimum sensitivity for the receiver, and then turned clockwise until the plate current reading of the signal relay tube is approximately one milliampere less than the former reading. For example, if the plate current which flows through signal relay No. 4, in Figure 113, reads 7 milliamperes with the sensitivity control set to the extreme counter-clockwise point, the control would be turned clockwise so that the average reading would be approximately 6 milliamperes. Bursts of static would then drive the signal relay current below the drop-out value and the contacts which initiate selector action would be occasionally or continuallly chattering, depending on existing noise conditions. The use of a sensitivity control is necessary; since if the auto alarm was permanently adjusted to respond to a 500-microvolt signal, during the heavy static season, and especially in the tropics, the signal relay would be de-energized most of the time and the receiver would be "blocked," insofar as ability to receive the auto alarm signal is concerned. In the event that this condition occurs, that is, where an increase in static level sufficient to drive the signal relay current below the drop-out value occurs, and continues for more than 3.5 seconds, warning lights installed beside each alarm bell will be turned on and will remain lighted until the static reduces in value, or the sensitivity control is set to the proper point for the new level.

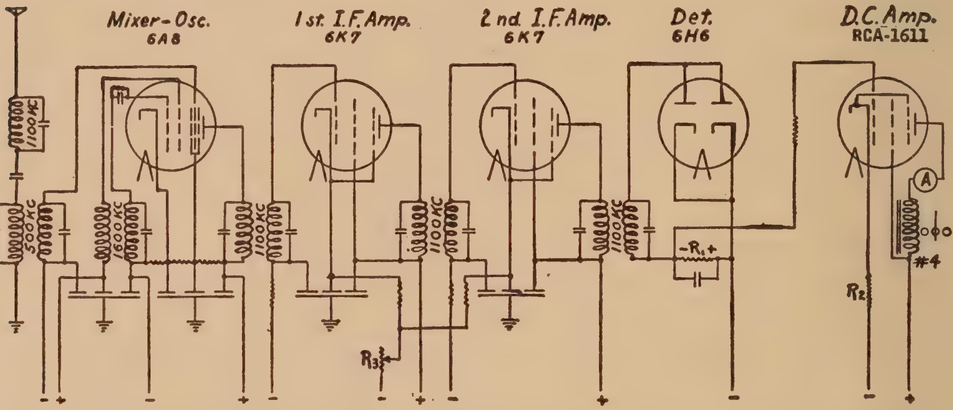

Fig. 113. Simplified schematic circuit diagram of the superheterodyne receiver used to supply the signal energy to the selector unit in the Radiomarine Automatic Alarm.

(*d*) *Explanation of Auto Alarm Selector Action.* The selector unit functions with three selector tubes and a voltage regulator tube. In this action the principle used is one of current decay in a series RC circuit, and the network of resistors and capacitors in the grid circuits of the individual selector tubes cause a time delay. The elapsed time of signal duration is measured by these RC circuits.

Referring to Figures 113 and 114, the selector action is as follows: An incoming signal of 500 microvolts or greater, of either A–1, A–2 or B emission, between 487.5 and 512.5 kc. produces a d-c voltage across the diode resistor R_1 of the correct polarity, as indicated in Figure 113, to reduce the plate current, I_b, of the d-c amplifier or signal relay tube below its drop-out value. Contacts *AM* (*A* refers to "armature" or moving contact, *B* to "break" and *M* to "make" contacts when relay is energized) are normally closed since relay No. 4 (Figure 114) is energized when no signals are being received. The reduction of I_b of the relay tube therefore causes contacts *AB* to be closed, which applies charging voltage E_g, developed by the voltage regulator tube, to C_1 through R_1. Since the grid-cathode circuit of

VT-1 is connected across C_1, as C_1 charges, the grid of VT-1 becomes less negative and eventually plate current, Ib_1, in the output of this tube begins to flow, gradually increasing to several milliamperes. Thus if a signal persists for 35 seconds Ib_1 becomes 5 milliamperes and relay No. 1 closes contacts *AM*. These contacts apply six volts obtained from the storage battery to the "notch" coil of the stepping switch No. 6, which moves up one step and the warning lights go "on." The coil of auxiliary relay No. 5 is in parallel with the notch coil of the stepping switch and, therefore, contacts A_1M are made. This starts C_2 charging through

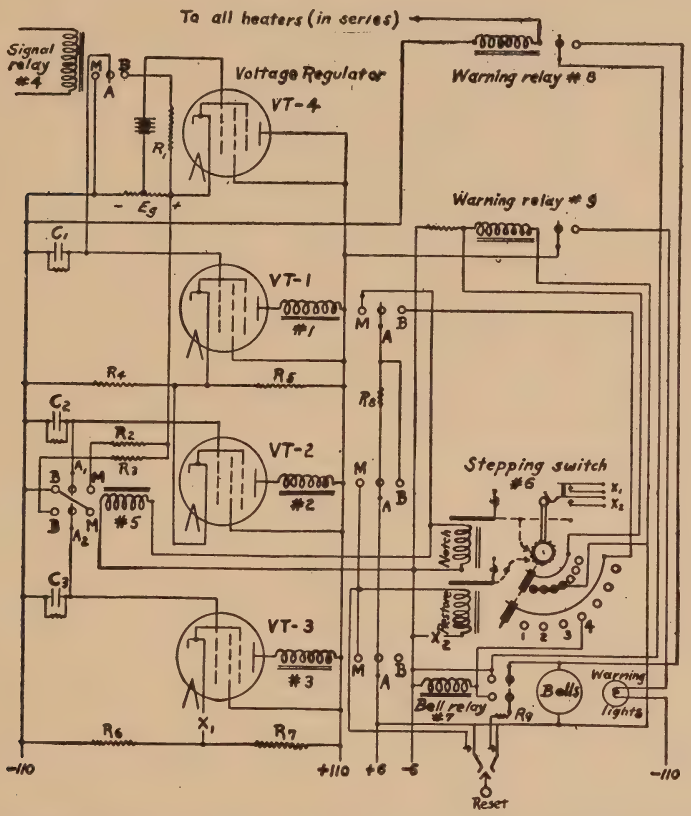

FIG. 114. Simplified schematic circuit diagram of the selector unit used in the Radiomarine Automatic Alarm.

R_2 and if the signal persists up to or greater than 4.5 seconds the plate current, Ib_2, of VT-2 becomes 5 milliamperes, which closes selector relay No. 2, and its contacts *AM*, in turn, apply six volts to the "restore" coil of the stepping relay. As soon as *A* leaves *B* of selector relay No. 2, resistor R_8 is inserted in series with the notch coil and auxiliary relay coil to prevent damage to the low resistance notch coil, due to an over-long signal or continuous "blocking" by static. The warning lights continue to glow until the signal stops or has a slight break in it. A break in the received signal allows signal relay No. 4 contacts *AM* to return the grid of VT-1 to a value greater than that required for plate current cut-off, which allows No. 1 relay contacts *AM* to open, thus removing the voltage from the "notching" coil and auxiliary relay No. 5, in turn allowing the "restore" coil of the stepping switch to return the lever wiper to normal. Contacts A_1B of auxiliary relay No. 5 then bias the grid of VT-2 beyond cut-off and allow selector relay No. 2 to open contacts *AM*, which removes the six-volt supply from the restore coil of the stepping switch. VT-1 thus serves to check the minimum length of a dash (dashes less than 3.5 seconds do not actuate the stepping switch), and VT-2 serves to check the maximum acceptable length of dash (dashes greater than 4.5 seconds energize the restore coil of the stepping switch which "restores" when the signal stops). Four dashes, if greater than 3.5 seconds and less than 4.5 seconds would then actuate No. 1 relay four times and the stepping switch wiper would rest on Contact 4. Then if a break occurs at the end of the fourth dash, contacts *AB* of No. 1 selector relay are closed which applies six volts to the bell ringing relay No. 7. Once closed, this relay applies six volts to the bells and is held closed by its auxiliary or hold-in contacts. In order to stop the bells the reset button on the auto alarm panel must be pressed. The bells are not allowed to ring until the fourth dash is broken (and within prescribed limits), since if this was not done three correct dashes and the fourth one of *any* length greater than 3.5 seconds would cause an alarm.

Selector tube VT-3 serves two purposes. If one, two, or three correctly timed dashes are received, the stepping switch wiper comes to rest on contact 1, 2 or 3 respectively and would remain in one of these positions indefinitely until another dash was received, which would then ring the bells. This is, of course, improper operation. In order to prevent such a condition the grid of VT-3 is normally connected to the charging voltage E_g through charging resistor R_3. The cathode circuit of VT-3 connects through interlock contacts X_1 on the stepping switch, which are open when the stepping switch is on the zero or "normal" contact only. Thus after a "notch" has occurred auxiliary relay No. 5 contacts A_2M are closed which biases the grid of VT-3 to its below cut-off value as determined by voltage divider resistors R_6 and R_7. At the conclusion of the dash auxiliary relay No. 5 contacts A_2B are made and after an interval of five seconds plate current, Ib_3, flowing in selector relay No. 3 reaches a value of 5 milliamperes, thus closing No. 3 relay contacts *AM*. These contacts in turn apply six volts to the restore coil of the stepping switch which will then be returned to normal. In the event that the second or following dash is completed within five seconds from the end of the previous dash, selector relay No. 3 does not close contacts *AM*. This then allows the maximum space between dashes to be the difference between five seconds and the initial closing time of relay No. 1, or 1.5 seconds. Such a method provides the proper checking of spaces. If an attempt were made to check spaces directly, any form of interference occurring during the space would "fill in" and cause an error in timing.

In order to indicate line voltage failure as well as tube heater burn-out, warning relay No. 8 is connected in series with all tube heaters which in turn are heated from the ship's 110-volt line. A failure of either tube heater or line voltage will cause the alarm bells to ring. The bells will, of course, stop ringing if the line voltage is restored. A test button is provided on the auto alarm panel which, when held in, prevents the bridge and operator's room bells from ringing during routine testing of the auto alarm receiver and selector.

Warning relay No. 9 is connected across the storage battery through a series resistor. Failure of the battery supply will allow relay No. 9 to de-energize and turn on the warning lights at each bell location. Warning of power failure is therefore obtained except for simultaneous failure of both the 110-volt ship's line supply and the storage battery. The chances of simultaneous failure are very remote.

In order to prevent normal changes in the 110-volt d-c ship's supply from impairing the timing of the selector circuits the grids of the three selector tubes are supplied with a regulated source of voltage from the voltage regulator tube VT-4.

(*e*) *Summary of Warnings Indicated by Lights and Bells.* Warnings given in list (3) below are to be expected and indicate that the auto alarm is functioning correctly, whereas, warnings given in (1) and (2) should be investigated as to their cause.

(1) *Bells ringing* may be caused by
  Receipt of auto alarm signal.
  Receipt of a false auto alarm signal caused by a fortuitous combination of static and keyed interference.
  Loss of ship's line voltage.
  Tube heater burn-out.

(2) *Warning lights burning continuously* are caused by
  Receipt of a continuous signal from a transmitter whose key is being held down for a period considerably greater than 4.5 seconds.

Sensitivity control set too high for the prevailing noise level.
Loss of 6-volt battery supply.

(3) *Warning lights burning intermittently* are caused by
Occasional long bursts of static.
Transmitter testing using dashes slightly longer than 3.5 seconds.
Heavy 500 kc. interference caused by several telegraph transmitters transmitting at the same time.

(*f*) *Operation of "Antenna-On-Off" Switch.* The circuit changes made with this switch in the "on" position or receive position which is used when the operator is "off watch" are given in list (*A*) below, and circuit changes made with the switch in the "off" position used when the operator is "on watch" are given in list (*B*).

(*A*) When in the "receive" position (operator "off watch")
- (1) Connects the main ship antenna to the auto alarm.
- (2) Opens transmitter key relay power supply circuit.
- (3) Connects the 110-volt supply to the auto alarm.
- (4) Connects the 6-volt supply to the auto alarm.

(*B*) When in the "off" position (operator "on watch")
- (1) Connects the ship antenna to the lightning switch.
- (2) Closes key relay power supply circuit.
- (3) Removes the 110-volt and 6-volt tube and relay supply voltages.
- (4) Places 6-volt battery on charge.

FREQUENCY VERSUS WAVELENGTH

$$f = \frac{V}{\lambda}$$

where f = frequency in cycles
λ = wavelength in meters
V = the velocity of propagation of electromagnetic waves, or 299,820,000 meters per second.

KILOCYCLES TO METERS, OR

Meters	Kilo-cycles	Meters	Kilo-cycles	Meters	Kilo-cycles	Meters	Kilo-cycles	Meters	Kilo-cycles
5	59960	500	599.6	1000	299.8	1500	199.9	2000	149.9
10	29980	510	587.9	1010	296.9	1510	198.6	2010	149.2
20	14990	520	576.6	1020	293.9	1520	197.2	2020	148.4
30	9994	530	565.7	1030	291.1	1530	196.0	2030	147.7
40	7496	540	555.2	1040	288.3	1540	194.7	2040	147.0
50	5996	550	545.1	1050	285.5	1550	193.4	2050	146.3
60	4997	560	535.4	1060	282.8	1560	192.2	2060	145.5
70	4283	570	526.0	1070	280.2	1570	191.0	2070	144.8
80	3748	580	516.9	1080	277.6	1580	189.0	2080	144.1
90	3331	590	508.2	1090	275.1	1590	188.6	2090	143.5
100	2998	600	499.7	1100	272.6	1600	187.4	2100	142.3
110	2726	610	491.5	1110	270.1	1610	186.2	2110	142.1
120	2499	620	483.6	1120	267.7	1620	185.1	2120	141.4
130	2306	630	475.9	1130	265.3	1630	183.9	2130	140.8
140	2142	640	468.5	1140	263.0	1640	182.8	2140	140.1
150	1999	650	461.3	1150	260.7	1650	181.7	2150	139.5
160	1874	660	454.3	1160	258.5	1660	180.6	2160	138.8
170	1764	670	447.5	1170	256.3	1670	179.5	2170	138.1
180	1666	680	440.9	1180	254.1	1680	178.5	2180	137.5
190	1578	690	434.5	1190	252.0	1690	177.4	2190	136.9
200	1499	700	428.3	1200	249.9	1700	176.4	2200	136.3
210	1428	710	422.3	1210	247.8	1710	175.3	2210	135.7
220	1363	720	416.4	1220	245.8	1720	174.3	2220	135.1
230	1304	730	410.7	1230	243.8	1730	173.3	2230	134.4
240	1249	740	405.2	1240	241.8	1740	172.3	2240	133.8
250	1199	750	399.8	1250	239.9	1750	171.3	2250	133.3
260	1153	760	394.5	1260	238.0	1760	170.4	2260	132.7
270	1110	770	389.4	1270	236.1	1770	169.4	2270	132.1
280	1071	780	384.4	1280	234.2	1780	168.4	2280	131.5
290	1034	790	379.5	1290	232.4	1790	167.5	2290	130.9
300	999.4	800	374.8	1300	230.6	1800	166.6	2300	130.4
310	967.2	810	370.2	1310	228.9	1810	165.6	2310	129.8
320	936.9	820	365.6	1320	227.1	1820	164.7	2320	129.2
330	908.6	830	361.2	1330	225.4	1830	163.8	2330	128.7
340	881.8	840	356.9	1340	223.7	1840	162.9	2340	128.1
350	856.6	850	352.7	1350	222.1	1850	162.1	2350	127.6
360	832.8	860	348.6	1360	220.4	1860	161.2	2360	127.0
370	810.3	870	344.6	1370	218.8	1870	160.3	2370	126.5
380	789.0	880	340.7	1380	217.3	1880	159.5	2380	126.0
390	768.8	890	336.9	1390	215.7	1890	158.6	2390	125.4
400	749.6	900	333.1	1400	214.2	1900	157.8	2400	124.9
410	731.3	910	329.5	1410	212.6	1910	157.0	2410	124.4
420	713.9	920	325.9	1420	211.1	1920	156.2	2420	123.9
430	697.3	930	322.4	1430	209.7	1930	155.3	2430	123.4
440	681.4	940	319.0	1440	208.2	1940	154.5	2440	122.9
450	666.3	950	315.6	1450	206.8	1950	153.8	2450	122.4
460	651.8	960	312.3	1460	205.4	1960	153.0	2460	121.9
470	637.9	970	309.1	1470	204.0	1070	152.2	2470	121.4
480	624.6	980	305.9	1480	202.6	1980	151.4	2480	120.9
490	611.9	990	302.8	1490	201.2	1990	150.7	2490	120.4

This table is used to convert wavelength in meters to kilocycles or kilocycles to meters. It should be remembered that the values are interchangeable, for example:

If the wavelength in meters is required for 1300 kilocycles, it can be found by referring to the figure 1300 in the " Meters " column. Here it is seen that the corresponding figure is 230.6 in the " Kilocycles " column.

Therefore,

1300 kc = 230.6 meters.

Example: To find the frequency in cycles of a wavelength of 200 meters:

$$f = \frac{V}{\lambda} = \frac{299{,}820{,}000}{200} = 1{,}499{,}100 \text{ cycles,}$$

or 1499 kilocycles.

The wavelength may be obtained by transposing the above formula:

$$\lambda = \frac{V}{f} = \frac{299{,}820{,}000}{1{,}499{,}100} = 200 \text{ meters.}$$

METERS TO KILOCYCLES

Meters	Kilo-cycles	Meters	Kilo-cycles	Meters	Kilo-cycles	Meters	Kilo-cycles	Meters	Kilo-cycles
2500	119.9	3000	99.94	4000	74.96	5000	59.96	7500	39.98
2510	119.5	3020	99.28	4020	74.58	5050	59.37	7550	39.71
2520	119.0	3040	98.62	4040	74.21	5100	58.79	7600	39.45
2530	118.5	3060	97.98	4060	73.85	5150	59.22	7650	39.19
2540	118.0	3080	97.34	4080	73.49	5200	57.66	7700	38.94
2550	117.6	3100	96.72	4100	73.13	5250	57.11	7750	38.69
2560	117.1	3120	96.10	4120	72.77	5300	56.75	7800	38.44
2570	116.7	3140	95.48	4140	72.42	5350	57.11	7850	38.19
2580	116.2	3160	94.88	4160	72.07	5400	55.52	7900	37.95
2590	115.8	3180	94.28	4180	71.73	5450	55.01	7950	37.71
2600	115.3	3200	93.69	4200	71.39	5500	54.51	8000	37.48
2610	114.9	3220	93.11	4220	71.05	5550	54.02	8050	37.25
2620	114.4	3240	92.54	4240	70.71	5600	53.54	8100	37.02
2630	114.0	3260	91.97	4260	70.38	5650	53.07	8150	36.79
2640	113.6	3280	91.41	4280	70.05	5700	52.60	8200	36.56
2650	113.1	3300	90.86	4300	69.73	5750	52.14	8250	36.34
2660	112.7	3320	90.31	4320	69.40	5800	51.69	8300	36.12
2670	112.3	3340	89.77	4340	69.08	5850	51.25	8350	35.91
2680	111.9	3360	89.23	4360	68.77	5900	50.82	8400	35.69
2690	111.5	3380	88.70	4380	68.45	5950	50.39	8450	35.48
2700	111.0	3400	88.18	4400	68.14	6000	49.97	8500	35.27
2710	110.6	3420	87.67	4420	67.83	6050	49.56	8550	35.07
2720	110.2	3440	87.16	4440	67.53	6100	49.15	8600	34.86
2730	109.8	3460	86.65	4460	67.22	6150	48.75	8650	34.66
2740	109.4	3480	86.16	4480	66.91	6200	48.36	8700	34.46
2750	109.0	3500	85.66	4500	66.63	6250	47.97	8750	34.27
2760	108.6	3520	85.18	4520	66.33	6300	47.59	8800	34.07
2770	108.2	3540	84.70	4540	66.04	6350	47.22	8850	33.88
2780	107.8	3560	84.22	4560	65.75	6400	46.85	8900	33.69
2790	107.5	3580	83.75	4580	65.46	6450	46.48	8950	33.50
2800	107.1	3600	83.28	4600	65.18	6500	46.13	9000	33.31
2810	106.7	3620	82.82	4620	64.90	6550	45.77	9050	33.13
2820	106.3	3640	82.37	4640	64.62	6600	45.43	9100	32.95
2830	105.9	3660	81.92	4660	64.34	6650	45.09	9150	32.77
2840	105.6	3680	81.47	4680	64.06	6700	44.75	9200	32.59
2850	105.2	3700	81.03	4700	63.79	6750	44.42	9250	32.41
2860	104.8	3720	80.60	4720	63.52	6800	44.09	9300	32.24
2870	104.5	3740	80.17	4740	63.25	6850	43.77	9350	32.07
2880	104.1	3760	79.74	4760	62.90	6900	43.45	9400	31.90
2890	103.7	3780	79.32	4780	62.72	6950	43.14	9450	31.73
2900	103.4	3800	78.90	4800	62.46	7000	42.83	9500	31.56
2910	103.0	3820	78.49	4820	62.20	7050	42.53	9550	31.39
2920	102.7	3840	78.08	4840	61.95	7100	42.23	9600	31.23
2930	102.3	3860	77.67	4860	61.69	7150	41.93	9650	31.07
2940	102.0	3880	77.27	4880	61.44	7200	41.64	9700	30.91
2950	101.6	3900	76.88	4900	61.19	7250	41.35	9750	30.75
2960	101.3	3920	76.49	4920	60.94	7300	41.07	9800	30.59
2970	100.9	3940	76.10	4940	60.69	7350	40.79	9850	30.44
2980	100.6	3960	75.71	4960	60.45	7400	40.52	9900	30.28
2990	100.3	3980	75.33	4980	60.20	7450	40.24	9950	30.13

Values of wavelengths not listed in the columns may be found by applying the decimal system. For example, it may be desired to find the frequency corresponding to 372 meters. There is no wavelength value given to correspond to this number. Therefore, by multiplying 372 by 10, we obtain the figure 3720, which is found listed in the " Meters " column and corresponding to a frequency of 80.60. Since the first value is multiplied by 10, we can move the decimal point one place to the right, giving us a value of 806.0 kc. Therefore, a wavelength of 372 meters corresponds to a frequency of 806 kc.

Symbols

μ = permeability (B/H)
π = 3.1416
ρ = volume resistivity
τ = thickness
κ = susceptibility
λ = wavelength in meters
δ = logarithmic decrement
ϵ = 2.7183 (base of Napierian logarithms)
η = efficiency (per cent)
θ = phase angle (degree or radian)
ϕ = angle
ψ = difference in phase
ω = $2\pi f$ (angular velocity in radians per second)
Φ = magnetic flux
Ψ = electrostatic flux
Ω = ohm
Υ = electric conductivity
$\mathscr{E}$ = electric field intensity
$\mathscr{F}$ = magnetomotive force
$\mathscr{R}$ = reluctance

a-f = audio-frequency (adjective)
a. f. = audio frequency (noun)
r-f = radio-frequency (adjective)
r.-f. = radio frequency (noun)
e.m.f. = electromotive force
m.m.f. = magnetomotive force
a-c = alternating current (adjective)
a. c. = alternating current (noun)
d-c = direct current (adjective)
d. c. = direct current (noun)
μf = microfarad or mfd
$\mu\mu$f = micro-microfarad or mmfd
h = henry
mh = millihenry
μh = microhenry
MΩ = megohm
rms = root-mean-square
rpm = revolutions per minute
rps = revolutions per second

Abbreviations

C	capacity (electrostatic capacity)	*d*	diameter; distance
E	effective electromotive force	*f*	frequency; cycles per second
I	effective current	*g*	conductance
K	dielectric constant	*h*	height
L	inductance	*i*	instantaneous current
M	mutual inductance	*k*	coefficient of coupling
N	number of conductors or turns	*l*	length
Q	quantity of electricity	*r*	distance from a point (radius)
R	resistance	*t*	time
T	period, or one complete cycle	*v*	velocity
W	watts		
X	reactance		
Z	impedance		

Greek alphabet

Letters		Names	Letters		Names	Letters		Names
Α	α	Alpha	Ι	ι	Iota	Ρ	ρ	Rho
Β	β	Beta	Κ	κ	Kappa	Σ	σ ς	Sigma
Γ	γ	Gamma	Λ	λ	Lambda	Τ	τ	Tau
Δ	δ	Delta	Μ	μ	Mu	Υ	υ	Upsilon
Ε	ε	Epsilon	Ν	ν	Nu	Φ	φ	Phi
Ζ	ζ	Zeta	Ξ	ξ	Xi	Χ	χ	Chi
Η	η	Eta	Ο	ο	Omicron	Ψ	ψ	Psi
Θ	θ	Theta	Π	π	Pi	Ω	ω	Omega

Signs

∝	proportional to; varies as	∠	angle
=	equal to	<	is less than
×	multiplied by	≪	much less than
+	plus; addition	>	is greater than
−	minus; subtraction	≫	much greater than
÷	divided by	∾	cycle
⊙	circle		

7.4 Mc
NSS CIRCUIT